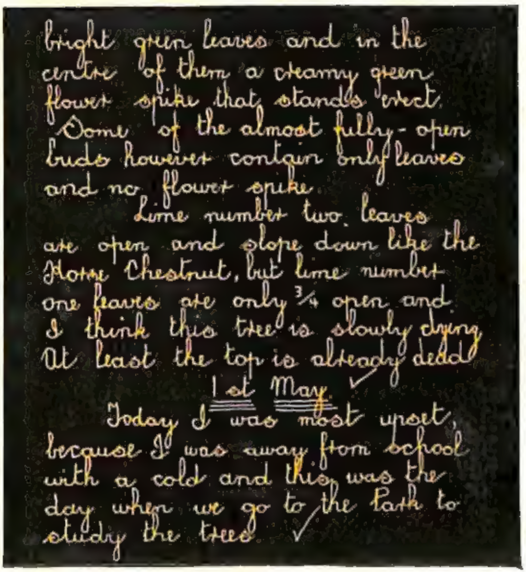
Nuffield Junior Science

Teacher's Guide 2


bright green leaves and in the
centre of them a creamy green
flower spike that stands erect.
Some of the almost fully-open
buds however contain only leaves
and no flower spike.
Lime number two leaves
are open and slope down like the
Horse Chestnut, but lime number
one leaves are only $3/4$ open and
I think this tree is slowly dying
At least the top is already dead
1st May
Today I was most upset,
because I was away from school
with a cold and this was the
day when we go to the Park to
study the trees.

Collins

Nuffield Junior Science

Teacher's Guide 2

Nuffield Junior Science

Teacher's Guide 1
Teacher's Guide 2
Apparatus: a Source Book of Information and Ideas
Animals and Plants: a Source Book of Information and Ideas

Teacher's Background Booklets:

Autumn into Winter
Science and History
Mammals in Classrooms

Nuffield Junior Science

Teacher's Guide 2

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Foreword

It is appropriate that the second group of books to be produced by the Nuffield Foundation Science Teaching Project should be designed to help in the primary schools. For the emphasis on enquiry and involvement which is characteristic of 'Nuffield Science' is also a feature of the approach which many primary schools have adopted with striking success. The books produced by the Nuffield Junior Science team will, we hope, suggest topics and methods to many teachers who are interested in the contribution which science can make to the education of younger boys and girls.

The Junior Science, like the other Nuffield courses, has many parents. Practising teachers (particularly, of course, the members of the Junior Science team), the Consultative Committee, and the Schools Council have all played a large part; and a particular feature of this project is that the Local Education Authorities concerned in the trials of the material have set up science centres—a move which should have far-reaching results in encouraging local initiative in curriculum development. In a number of areas, the trials have been conducted simultaneously with the trials of the Nuffield Junior Mathematics Project, and this has provided a useful link between the two activities.

It is even more true of the junior science than it was of the Nuffield 'O' level Science that the process of helping teachers with new courses is a large and continuing one. A beginning has been made, and the Schools Council (with the co-operation and support of the Foundation) is taking responsibility for the next stage. These books are therefore the first fruits of what will be a larger harvest.

Brian Young
Director of the Nuffield Foundation

Contents

'Children are people. They grow into tomorrow only as they live today.'

JOHN DEWEY

Introduction

This volume contains a number of reports of the work done by classes before the pilot trials of the Junior Science Project, so that teachers can read about them for themselves. In this period, members of the Junior Science team were working with the class teachers, and the classes had been chosen to cover as many of the different conditions as possible. Clearly, the time and facilities available to us were necessarily restricted and, in any case, to report on the complete range of buildings, children's ages, teachers' backgrounds and degrees of experience, and so on, would require several volumes the size of this one. Nevertheless, we believe that the examples quoted are fairly comprehensive.

We hope that the work described will teach through example, and that teachers will select and read what seems relevant to them. It was never intended that all the examples should be read through like a novel. Teachers who have tried the materials have used the classroom examples in a variety of ways. Some, who were not widely experienced or did not have a wide background of science, and who for various reasons felt apprehensive and insecure, decided on a piece of work and imitated what they read there. By doing this, they felt that they knew what materials and books to introduce, what kinds of questions to ask, and what kind of replies to expect. In other words, they felt in control of the situation. Some of those who began in this way soon found themselves forgetting about the examples they had read and beginning to feel confident enough to launch out on new problems that the children raised.

Others merely wanted the example to prepare them to start on a kind of work with which they were already familiar, but in an area they had not previously explored. Still others used the examples as a stimulus to start them along lines which were completely new to them.

However they are used, we hope that the teacher will take confidence from them and eventually grow free of them.

The key on the following page is a brief guide to the categories of information covered.

Key to the classroom examples

	Title	Age	Ability	Type of Area	Boys or Girls
1	*Rats*	5	Full range	Urban	Both
2	*Colours and sounds, but mainly a hamster*	5	Full range	Urban	Both
3	*A teacher's diary*	5	Full range	Urban	Both
4	*Spirals and natural dyes*	5-6	Full range	Urban	Girls
5	*Bones*	6-7	Full range	Suburban	Both
6	*Day-old chicks*	6-7	Full range	Urban	Both
7	*Electricity*	6-7	Full range	Urban	Both
8	*The lawn*	6-7	Full range	Urban	Both
9	*Sound I*	6-7	Full range	Urban	Both
10	*A sunflower*	6-7	Full range	Urban	Both
11	*Rainbow colours*	6-7	Full range	Urban	Both
12	*Parkland*	7-11	Full range	Rural	Both
13	*Stone-age art materials*	7-11	Full range	Rural	Both
14	*River and woodland visit*	7-15	Full range	Rural	Both
15	*A schools broadcast*	7-8	Full range	Rural	Both
16	*The sea shore*	7-8	Upper of 2 streams	Rural	Both
17	*Waste ground*	7-8	Full range	Urban	Both
18	*Light*	8-9	Upper of 2 streams	Suburban	Both
19	*Central heating*	9-10	Full range	Urban	Both
20	*Leaves*	9-10	Upper of 2 streams	Urban	Both
21	*A nature trail*	9-10	Full range	Urban	Both
22	*A school playing field*	9-10	Full range	Urban	Both
23	*Sound II*	9-10	Full range	Urban	Both
24	*A story read to the class*	9-10	Lower of 2 streams	Rural	Both
25	*A visit to the school grounds*	9-10	Full range	Suburban	Boys
26	*Bricks and glass*	9-11	Full range	Urban	Both
27	*Sea-coal for sale, and candles*	9-11	Educationally subnormal	Urban	Boys
28	*A weather saying, birds, and a woollen mill*	9-11	Full range	Rural	Both
29	*Urban wasteland*	9-11	Full range	Urban	Both
30	*A woodland visit*	9-11	Mainly below average	Urban	Both
31	*Animals in the school grounds*	10	3rd of 4 streams	Urban	Both
32	*Angling*	10-11	Average and below	Urban	Both
33	*A farm visit*	10-11	Full range	Suburban	Both
34	*A riverside*	10-11	Full range	Rural	Both
35	*Birds and other things on the playing fields*	10-11	Full range	Urban	Both
36	*Lead smelting*	11-12	Full range	Rural	Both
37	*Field excursions*	11-12	Full range	Rural	Both
38	*Felling a tree*	12-13	3rd of 4 streams	Suburban	Both

1 Rats

Class	5 years. Full range of ability
Class number School roll	28 boys and girls 136
Term	Autumn
Building	Built between the two wars. Single-storey around a square playground.
Classroom	Simple square room with windows along two opposing walls. Storage cupboards, but no store room. No main services. Full, but not overcrowded.
School environment	Brick classroom buildings with asphalt playground and school playing field. On one side, a busy road, and housing on the other three sides.
Local setting	East Midlands. A housing estate in a small town, with light industry alongside a main railway line. Surrounding area farmland, with easy access from the town. Nearest large city twenty-five miles away.

Two white rats were borrowed from a local college half-way through the autumn term; and from the start, the children were extremely interested. They wanted to be near the animals, but while the boys wanted to pick them up, the girls were more reticent, preferring to look at them and stroke them while the boys held them.

During the afternoon, one or two of the boys gave one rat a ride on the toy train, but while they were doing this the other escaped from the boy who held it and took cover behind a heavy cupboard. They tried to recapture it by tempting it with food, but the animal was still at large when afternoon school ended, so before she went home the teacher put the cage on the floor and left food and bedding straw nearby.

Next morning there was great amusement, for although the rat was not to be seen, neither were the food and straw. The rat had taken them into a corner behind the cupboard.

Two of the boys were very anxious to help, and kept a constant and quiet watch. The episode ended when the children put a dish of water on the floor and the rat was so thirsty that it came out to drink and allowed itself to be caught.

The children were now interested in the way the other rat received its lost companion and crowded round the cage. They noticed that the escaped rat seemed only to want

water, while the other one climbed over its companion's back, sniffing and nibbling as it did so.

Several children were concerned about the rats' welfare and wanted to be sure that there would be plenty of food and water for them over the weekend. Alexander and Jan were keen to clean the cage, and did so efficiently.

At this point the children realized that they had difficulty in telling the rats apart, and a group of them discussed with the teacher how they could be marked. It is interesting to note that it was some time before they realized that they needed to mark only one rat. Ultimately, two of the boys held one of the rats while a girl marked its tail with a felt pen.

This rat was now known as Perky, the unmarked one being Pinky, and now that the rats were easily distinguishable, the children's interest rose considerably. It was as though the animals had suddenly developed separate characters, and even the more reluctant girls were now keen to handle them and make up stories about them.

The colour of the rats' eyes attracted attention. They were pink and the 'black spots' (pupils) were hardly noticeable. The children compared them with human eyes which, according to the children, were not pink. They talked about eyes in general, their colour, and their position on the head.

Discussions ranged over a variety of topics and the children steadily extended and practised their vocabulary. They used words like 'pairs', 'single', 'together', 'long', 'narrow', 'several', 'many', 'sharp', 'warm', 'soft', 'thin', and 'pointed'.

Heart beats were described as 'bangings', paws and feet 'tickled', eyes had 'puddles' (pupils), and tails were 'like worms'. One girl said that whiskers 'twinkled', explaining that 'they move ever so quickly in and out like stars'. Several boys objected to the tail being described as a worm because, they said, it was not brown and did not have rings.

There was a great deal of number work. How many toes? How many fingers? They counted in twos, besides counting how many fingers and toes the two rats had between them. Some children—who thought that the long and narrow tails looked like long narrow ladders—wanted to know which rat had the longer tail. They held a piece of wool against each rat's tail and compared the two lengths of wool by placing them alongside each other. The teacher tried placing the wool on a ruler and counting off the numbers, but this had no meaning, and consequently no interest, for the children.

The children did not develop a theme or go on searching along any single line of thought, and without continual guidance by the teacher it is unlikely that any discussion would have gone any further than superficial statements.

There was little or no attempt to follow up questions and statements with experiment and the teacher found that almost inevitably any suggestions of experiment came from her. She decided that it should be a natural outcome of the child's interests and to impose it on the children would defeat the object of experiment.

The children's discussions never kept to the subject from which they started, and conversations flowed off at tangents into the most unlikely topics. Individual conversations, of course, were always much more rewarding than class discussions.

There were, however, exceptions to this rule. For instance, some of the girls were afraid that the rats would feel the cold at night, and this led to a small group discussion on the animals' fur in contrast to human skin and the need for layers of clothing. Someone said that we use animals' fur for coats, and a lively discussion followed about the things we get from animals: meat, bones, skins, leather, wool, and milk, one child saying that 'birds give us trees' (a reference to seed dispersal).

There was an attempt to experiment when one boy noticed that the rats placed their feet as we do and did not hop or jump. They compared the rats' leg movements with those of a horse—walking or trotting—and wondered if a rat which moved quickly would use its legs like a horse galloping. They put their desks together, put the rats on top, and then

tried to make them move quickly by pushing them and making banging noises behind them. There was no success and the experiment was abandoned for something more rewarding.

The children liked the way the rats drank, like babies, from the water bottle, and the way they nibbled food held in their front paws. This reminded one child of pictures he had seen of squirrels holding nuts in a similar manner.

There were periodic bouts of painting, initiated by intermittent exciting incidents. Thus, when the rat escaped there were pictures of it hiding behind the cupboard, and when a new cage arrived, there was renewed activity.

As Christmas approached, interest in the rats subsided and they were collected from the classroom towards the end of term and returned.

The teacher's summary of the situation is as follows:

'The children reacted with lively interest, but their stage of development is such that they did not delve deeply into any particular topic. Their interest was high one minute and then flagged quickly as other interesting situations developed.

'At first, the girls showed some distaste for handling the rats but later became very attached to them and took great care over feeding, cleaning, and handling.

'Individual and small group conversations led to more concrete observations than did class discussions. There were opportunities for social training, language development, work with numbers, and the usual creative activities.

'The things that interest children are always surprising to an adult. For instance, they accepted colour, pink eyes, quivering noses, and whiskers without question, but they wanted to know why the animals slept together and if they played games after school had ended.'


observation of
rats' behaviour
when reunited
devising
methods of
capture
handling chiefly
by boys
escaped rat
art
materials
from animals
care of
animals
ride on
train
fur
vocabulary
extension
measurement
of rats' tails
RATS
art
whiskers
eye colour
vocabulary
discussion on eyes
heart beats
vocabulary
movement
vocabulary
marking for
identification
experiment:
do rats gallop
like horses?
feeding
more handling,
this time by
girls as well
comparison
with other
animals

2 Colours and sounds, but mainly a hamster

Class	5 years. Full range of ability
Class number School roll	41 boys and girls 200
Term	Autumn
Building	Three years old
Classroom	Modern and pleasant. Sink unit and plastic covered bench with built-in cupboards underneath, along one wall.
School environment	On high ground overlooking town. Serving a private housing development and a council estate.
Local setting	North-east England. A market town; local industries include iron foundry, clothing factory, agriculture, and forestry.

Colours

A group of children began to play with the following materials which they found near the sink in their classroom:

Containers of many shapes and sizes, e.g. sweet jars, milk bottles
Confectioners' food colours in bottles fitted with droppers
Liquid detergent
Olive oil
Powder paint
Potassium permanganate crystals
Alka-Seltzer tablets
Measuring jugs
Funnels
Sieves
Eye droppers

For several days they concentrated exclusively on water, and filled and emptied the containers. Just when it seemed that they were not going to touch the colours, Helen put some potassium permanganate crystals into her jar of water. The others gathered round.

'It's turned into paint.'
'No. It's coloured water.'
'It's purple.'
'It was purple powder.'
'No' (shaking carton) 'it's bits of stuff.'

The teacher introduced the word 'crystals' to describe the 'bits'. The rest of the children in the group began to look with interest at the colours. Helen put a few drops of blue food colouring into a large jar of water. The children observed closely. There were more comments and attempts to explain. Often the explanations were modified by other children.

'It's ink.'
'Well, it's like ink.'
'It's all cloudy.'

Helen reached out and put an Alka-Seltzer tablet into it.

'It's like a fire.'
'It's dissolving.'
'There's bubbles blowing up.'
'It's fizzling.'
'You mean fizzing.'
'It's all melted.'
'It must be hot.'
'Yes. It's all boiling.'

The teacher suggested they should feel the jar to see if it was hot enough to boil. A few insisted it was boiling even though the jar felt cold. The teacher did not press the point. She showed them how to use an eye dropper and put one or two drops of olive oil onto the water in a jar. There were many comments, and Alan said, 'One drop of squeezy will take all that away.' He picked up the bottle of detergent and squeezed some in.

ALL: 'It hasn't gone.'
ALAN: 'That's because it's cold water.'
Helen stirred it and the oil vanished.
'It's in the bubbles.'
'It's down at the bottom.'
'The squeezy washed it away.'

The teacher encouraged the children to talk to her and to one another about what they were doing, and the above conversations show the kind and quality of their observations and comments. Clearly, they were thinking hard about what they saw and were trying to put their ideas into words.

The children returned to the colours. Some put two or three into their jars and were fascinated to see them form layers before mingling. Others began to paint with those they had mixed. Finding them too pale, they added more food colouring but this still did not make them strong enough so Jane used the colour straight out of the bottle. The rest followed her lead.

Suddenly they noticed that the purple colour which they had made with potassium permanganate had turned brown on the paper. This caused much comment, for example,

'It's brown when it dries.'
'The crystals are purple.'
'But if you look at them one way they shine brown.'
'That's where the brown comes from.'

The children filled the sink with water, and dropped spots of colour into it, watched silently and intently as the colours mixed, and then ran the tap to see the clouds of colour and bubbles. The teacher suggested dropping colours from an eye dropper onto absorbent paper. They enjoyed making patterns when they did this, and watching the colours merge. Often their combinations of colours (e.g. black, royal blue, aquamarine, and orange) and the distribution of colour on the paper produced striking effects.

Two children were cleaning out the cage of the class's hamster, and were intrigued by a black sunflower seed which had fallen into the water dish and was colouring the water. They took some of the black seeds to the group who were working with the colours and asked them to try them in the sink. After a few minutes, when no colour had appeared, they began to talk:

'It was in the water a long time.'
'Will it make Bobby's [the hamster's] tongue purple?'
'It must have soaked in the water.'

The teacher suggested that they should pick out a lot of black sunflower seeds from the hamster food and try soaking them. They put a handful into a jam jar half full of water. In about half an hour the water was purple and next day the children were very excited to find it almost black.

'We've made purple paint.'
'It isn't paint. It's dye.'
'The seeds are still black so the water will get blacker.'
'Stir it up and some more will come out.'
'Will it stain?'
'We could make purple cloth.'

The teacher promised to bring some cloth to see if it would dye. Meanwhile, children had brought some maize from the hamster food, dried rose hips, and geranium flowers to soak.

They were disappointed when none of these produced dyes, but were interested to see that after a day or two the maize and rose hips had swollen to their original size.

'They've soaked the water in.'
'That's what was the matter with them when they were shrivelled up. All the water had dried up.'
'My mummy soaks peas like that.'

The teacher provided some cotton material and two cold water dyes, one red and one blue. The children dyed some cloth in the cold water dyes, and some in the dye made from sunflower seeds which made it a greyish lavender colour. The liquid from the rose hips was also tried and tinted the cloth pale yellow. The children talked into some of the empty sweet jars and were amused and fascinated by the sound of their voices. They discovered that if they put their mouths in the mouth of the jar and covered the rest of the space with their hands, the others could not hear them when they spoke, even though they were standing quite close. Paul spoke into his jar, quickly put the lid on, and said, 'I've got all my words in there.' This delighted the rest of the group.

Sounds

Seven children began to play with the following collection:

Musical instruments, e.g. drums, xylophones, triangles
A bottle xylophone
Beaters made from various materials, e.g. wood, metal
Containers of many shapes and sizes made of various materials, e.g. cardboard, plastic, glass, metal
Scrap wood
Beans, peas, rice, lentils, wheat, oats, sand, pebbles
Kitchen scales and weights

After they had played freely with these for a few days, the teacher tapped two containers, one of which produced a high note and the other a low one. The children listened and she asked if they thought they could get different notes from other containers. They began to compare them, tapping each with drumsticks or other beaters.

Later, the teacher put some pebbles in a box and shook it. The children listened and then tried it themselves. Soon they were putting other things, such as sand, peas, or oats, into containers, and shaking them to see whether they gave a high or low note.

Juliet chose two identical polythene jars and put lentils in one and rice in the other. She showed them to the teacher and, shaking the lentils, said 'That's a high note', and sang it. Then she said, 'And this is a low note', and sang it.

Alan B. tried putting twice as much in one container as in the other. He weighed 2 oz. of peas and 1 oz. of wheat and put them in similar glass jars.

Many combinations were tried and the children devised guessing games. One would shake a container and the other had to say what was in it. Since they had not mastered the names, they answered by touching the jar containing whatever they thought it was. Another game was to show two containers to another person and ask him to guess which made the higher note. They shook the containers to show whether the guess was right or wrong.

The children did not appear to connect the pitch of the sound with factors like the type of container or the size or quantity of the material inside. They put sand in one container and told the teacher that it made a high note. She asked if they had any idea why. Susan replied, 'Because it's soft,' and Martin, 'Because it's little.' Sharon said, 'Because it's light.'

The last answer exposed one of the problems in establishing a child's degree of understanding, that of language. Did Sharon mean that the individual particles of sand were light in weight, or light in colour, or that a given volume of sand was light in weight compared with, say, an equal volume of water? The teacher constantly had to probe to find out

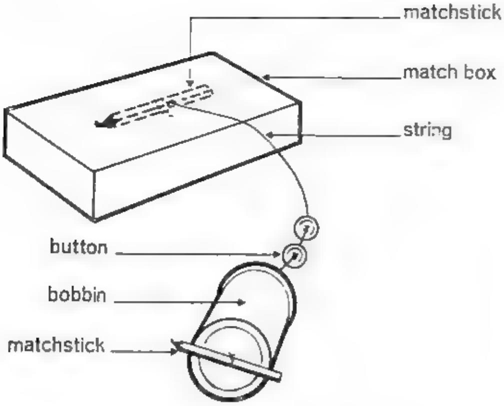


FIG. 1. Charles's match box radio.

precisely what the children were trying to say. In this case, Sharon was referring to the weight of individual particles, but the teacher found that the whole group also thought that a bucket full of sand would be light in weight. She therefore helped them to half-fill a bucket with sand first, and then, in turn, paper, leaves, water, wood, and cardboard. The children lifted the bucket each time and declared that sand was the heaviest. Martin said that wet sand would be even heavier so they tried that as well. They enjoyed filling and lifting the bucket, but liked it even better when they tipped out the wet sand and spent the rest of the morning moulding it and making sand pies.

The teacher hung up an assortment of cans, a sea shell, half a coconut shell, a cymbal, and a triangle. She also made a bottle xylophone and provided an assortment of beaters. The children played a good deal with the bottle xylophone and seemed to enjoy the ring of the notes. One or two added more water to some of the bottles or tipped some out, but did not appear to notice the change in the sound and certainly said nothing about it. They showed little interest in beating the cans or the sea shell or coconut shell, in fact they hardly touched them, as they preferred the sound of the cymbal and triangle. They also neglected some 'one-string guitars' which the teacher had made and she wrote, 'I wondered if the sound from these was too soft.'

Charles caused great excitement when he brought to school a match box 'radio' which his older brother had made. This is illustrated in figure 1.

Most of the boys wanted to try it and when the teacher asked if they would like to make one for themselves they all said they would. She provided the string, match boxes, and other essential materials and then left the boys to work by themselves while she helped the girls with a collage picture. The boys were completely engrossed. Those who finished their 'radios' first tried them out and then helped those who were finding it difficult. By playtime, almost every boy had a 'radio'. After play they tested them, letting the girls listen, and vice versa. They made many sounds, for example:

1 Flicking the match box with a finger nail
2 Swinging the string with the bobbin in the middle and then pulling it tight ('aeroplane sound')
3 Rubbing the bobbin up and down the string ('a saw')
4 Plucking the string with fingers ('guitar')

They were amazed at the loudness of the sound from the 'earphone' (match box) when nothing could be heard by anyone else even though they stood very near.

A hamster

The children had acquired their hamster in the fourth week of term. For the first three weeks, Jill had continually been telling them about her pet hamster at home, which had had babies. Then her mother offered them one, and the teacher accepted. Jill brought it next morning, while the teacher brought a new cage. One or two children helped her to put medicated sawdust, food, bedding, and water into this, and then they stood it on a desk where everyone could see. The teacher, first asking everyone to keep quiet in case they frightened the hamster, put it inside. There was complete silence. The children

watched, fascinated, as it sniffed among the food. When it sat up to eat there was a gasp and a girl said, 'He's like a fairy.' Immediately, others began to comment and ask questions, for example:

'Isn't he lovely.'
'I love him.'
'Will he love us?'
'Can we touch him?'
'What is he eating?'
'What's the wheel for?'
'What's he called?'

They discussed their questions. The teacher explained that the hamster was still too timid to handle but they could begin as it settled down. Some of the boys knew that the wheel was for exercise. The hamster began to wash itself. This made the children laugh loudly and it hid in a corner of the cage.

The children talked about its age, colour, and food. Katy insisted on giving it some of her milk at playtime. All day, at least one child was pausing beside the cage to watch. Later, they decided the hamster ought to have a name. All of the names suggested were boys' and by a show of hands they chose 'Bobby'. The teacher asked the children to describe Bobby:

'He's nice.'
'He's little.'
'I think he wants his mummy.'
'He's soft and cuddly.'
'I think he's a lazy hamster.'
'He's fluffy.'

She chose a sentence and wrote it on the blackboard and the children copied it into their individual books and illustrated it with a picture. They talked about things which were fluffy and the teacher asked them to bring some of these to school. They brought cotton-wool, feathers, and pink lint among other materials. These were set out on a table, together with a powder puff and a fur brooch which the teacher contributed, and the children handled and talked about them.

A conversation about the baby hamster developed into a discussion about human babies. The children told the teacher what happened when their younger brothers and sisters went to the clinic, mentioning that they were weighed, and the teacher suggested weighing Bobby. The children shrieked with laughter.

'You can't weigh a hamster.'
'He won't stay on the scales.'

Helped by two children, the teacher put Bobby on the scales. They put their smallest weight, 1 oz., in the pan but the hamster was lighter. The children handled the weight and found it hard to believe that Bobby did not weigh that amount. They commented:

'Perhaps the scales are broken.'
'The scales are stuck.'

The teacher picked up some ¾ in. wooden cubes and asked if they could be used to weigh the hamster. The children were doubtful but they tried and it tipped the scales at six bricks. Several children became very interested in weighing the hamster and they began to do so twice a week. At the teacher's suggestion, they piled up the bricks they had used in a column each time, and stood it next to the column from the previous weighing. In this way they kept a record. The columns were easily knocked over so the teacher stuck wires in a piece of soft wood and they threaded the cubes onto the wires. Figure 2 shows how.

Later, the teacher showed them how to keep a record without using cubes which were

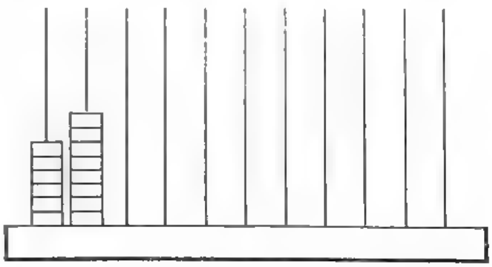


FIG. 2. The children made a standing graph of the hamster's increase in weight.

needed for weighing. They cut out squares of coloured gummed paper and stuck these on a chart in columns, one square representing one block. Thus they made their first block graph.

On one occasion while the hamster was being weighed it crept out of the scale pan and scrambled into the opposite one. The children declared that it could not be weighed in that pan and were surprised to find that it made no difference. Until this moment the teacher had not noticed that they had always weighed it in the same pan.

The children thought it was a very strange idea when the teacher suggested measuring the hamster. She asked how long they thought it would be and they guessed:

'Ten feet.'
'Twenty-seven inches.'
'Twenty feet.'
'Nineteen,' etc.

The teacher and children coaxed the hamster onto a ruler and found that it was three inches long. They thought it might be easier to measure it with string but it began to chew the string when they tried, so they gave this up. To help them see how the hamster was growing, the teacher made a large growth chart. The children cut the pieces of string the same length as the hamster and the silhouettes were made by drawing around the hamster, then cutting out the shape. The chart was filled in twice a week.

Most of the children were interested in the hamster's food. They brought vegetables from home and watched to see which it ate. At the teacher's suggestion, they cut off a carrot top and put it in a saucer of water to grow leaves for the hamster to eat. They sorted out the constituents of commercial hamster food and put them in separate dishes, labelling them to show which it liked and which it left. In a similar way, they displayed foods which they had brought from home for it. After watching it eat, they made decisions about which ones it liked. For example, they thought maize seeds were amongst these 'because he crunches them up fast and stuffs them into his pouch.'

They also speculated about the quantity of food the animal ate, and tried putting different quantities of hamster food (mixed grain) in its dish to find out. It seemed to take about a dessertspoonful in twenty-four hours so they put this amount in a glass jar and the teacher put a card beside it saying, 'Bobby eats one dessertspoonful in a day.' They calculated that it would eat seven in a week and showed this in another jar. The children were surprised at these amounts because they seemed so large for such a small animal. Then, when the hamster was eight weeks old, two children who were cleaning out the cage found its store of food. They said:

'He doesn't *eat* a spoonful a day. It's nearly all here.'
'Oh well! That doesn't matter. It's the same as his pouch.'
'He hasn't really eaten what's there. It's just to carry it in like a bag.'
'I suppose he'll eat it some time.'
'Of course he does. I've seen him scratching for it and eating it.'

They showed no further concern that their estimate of a spoonful a day was not accurate.

At appropriate times the teacher told the children a little about the life of hamsters in the wild but they showed no great interest. On the other hand, they were enthralled by extracts from a story about a hamster.* The teacher concluded that this appealed to them because it echoed their own feelings about the hamster, expressed in comments like these:

'He says he doesn't want any more.'
'He thinks he's in a circus.'
'Don't squeeze him, he'll cry.'

She also thought that it probably helped to foster kindness towards animals.

At the time of the school harvest festival they talked about corn, and the teacher mentioned that we did not eat all that the farmer harvested but saved some to sow the next year's crop. Martin asked, 'Will the

* Clarke, M. (1953) *Golden Hamster*. Wheaton.

corn in the hamster's food grow?' A group of children tested seeds from the packet to see. They sowed them in dishes filled with soil and watered them, so generously that the teacher thought they were unlikely to germinate. However, she resisted the temptation to intervene but suggested that they should show which kind of seed was sown in each dish by sticking a seed to the outside. The seeds grew and were watered and examined each day. The sunflowers attracted most attention because they had apparently 'popped out of the soil'. However, after reaching a height of about four inches the seedlings died. The teacher waited for comments but the children seemed to accept this fact without wondering why. She left the dead seedlings where they stood and noticed that when the children tidied the room they made no attempt to throw them out. Several days later the teacher was telling them the parable of the sower and was talking about the seeds which fell on stony ground when Mark broke in, saying, 'That's what's wrong with our seeds.'

TEACHER: What do you mean?
ALAN (*before Mark could speak*): Well, the soil is too thin. (*They were shallow dishes.*)
DAVID: And it's far too hard and stony. (*The soil contained a lot of clay and had dried hard.*)
MARK: And the sun shines hot in here.
NEIL: I thought that was as big as ours would grow.

Consequently, more seeds were sown, this time in carefully prepared soil in large plant pots. They grew well and the children followed their growth with keen interest.

The teacher put out a new pair of scales for the children to use. They were painted white and some of the girls remarked:

'They're like baby scales.'
'They're like the scales at the clinic.'
'We could weigh all the dolls on them.'

They brought cots from the Wendy house and borrowed eye droppers and coloured 'medicine' from the children working with colours. One girl brought a toy hypodermic syringe

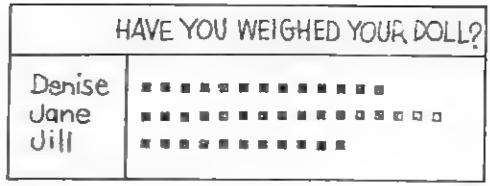


FIG. 3. Each (coloured) square represents a brick used in weighing.

from home. Then they devised nurses' uniforms from materials in the dressing-up box, and the clinic was ready. At consulting times, the 'mothers' waited in an orderly queue. The 'nurses' weighed each 'baby', gave it an injection, and dabbed it with cotton-wool. They also put drops into eyes, noses, and ears. Then they wrapped the 'baby' in a shawl and put it in a cot to rest while the 'mother' went to the Wendy house for a cup of tea.

The girls began to bring dolls from home, so the teacher suggested that they should write down the weight of each one. They were keen to do this and Lesley asked, 'Could we make a chart like Bobby's?' Accordingly, they weighed each doll with bricks and showed its weight on a chart. They wrote the names of the dolls down the side of this, and then cut out squares of coloured, gummed paper and stuck them on in rows, one square for each cube, as shown in figure 3.

For two or three weeks near the end of term the hamster's length remained at $5\frac{1}{2}$ in. and its weight at 19 bricks. The children seemed quite content at the $5\frac{1}{2}$ in. but many were keen that it should reach a weight of 20 bricks. The teacher wrote, 'It was almost like a game with a desperate feeling that 20 bricks must be reached. I even caught the feeling myself and found that we were weighing Bobby every day instead of the usual twice a week.' When it was twelve weeks old the hamster weighed 20 bricks. There was great excitement and the children rushed to put 20 bricks on a wire and 20 squares on the chart.

Throughout the term children had watched the hamster closely and had been interested in

all that it did. Their growing knowledge and interest found expression in a number of forms. They talked about it a great deal and made pictures, one of which is shown in plate 1. As they mastered the mechanics of writing, their pictures were accompanied by more and more writing, and much of it showed how keenly they observed—for example, 'His whiskers twitch and twinkle all the time'. Those who modelled the hamster in clay all used pieces which were approximately the same size as Bobby even though the teacher normally encouraged them to make large models, and they seemed to work as much from the feel of the hamster as its appearance. They also expressed some of its poses and actions in their movement lessons, for instance, rolling up in a ball to sleep, washing, crawling up a ladder, and climbing along the cage bars.


recording growth
measuring
amount eaten
block graph
depth and kind of soil for seeds
food preferences
doll's clinic
weighing
growing seeds from food packet
care of animal
sorting food
textures—fluffy, furry, etc.
feeding
dye from sunflower seeds
A HAMSTER
fur
making dyes
absorption of water by dried fruits
observation, handling, discussion
stories
picture making
naming
modelling
vocabulary
movement
reading
free writing
MUSICAL INSTRUMENTS, SHAKERS, ETC.
free play
COLOURS, LIQUIDS, CONTAINERS
changing water levels in bottle xylophone
making shakers
MIXING liquids
colour mixing
pitch of sounds made
effect of detergent on oil in water
patterns made by drops of coloured water
guessing games
painting with different concentrations

3 A teacher's diary

Class	5 years. Full range of ability
Class number School roll	39 (increasing to 49) boys and girls 220
Terms	Autumn and spring
Building	Red brick, built 1902. A three-tier school accommodating infants on the ground floor and juniors and seniors above—all sharing a central hall.
Classroom	Originally had galleries with iron-framed desks fixed to a series of steps. Windows very high and lower part of walls covered with brown tiles. Sink with hot and cold water, but storage space limited—conditions cramped for this large class.
School environment	Surrounded by large paved playgrounds shared by the three departments. A few trees remain against the railings of one side.
Local setting	Once a residential area on the outskirts of a large sea port in north-west England; now almost completely industrialized with many factories in the vicinity of the school, and main trunk roads with heavy traffic running through the area. A park is not far away.

Here are a few extracts from a diary kept by the teacher. In the autumn term there were thirty-nine children, but after Christmas, twelve of the older children were moved to another class to make room for twenty-two newcomers, bringing the total to forty-nine. The teacher made the old fashioned classroom an exciting place for the children by offering a wealth of materials and encouraging them to explore their environment freely.

September 22nd

Children sighted a weather balloon and came in from the playground talking about it and asking questions—'What is it?' 'What is it doing up there?' We talked about the people who need to know about the weather—ships' captains, air pilots, farmers—and the children thought the wind was the most important thing for them to know about and wondered how a balloon could 'measure the wind'. Explained simply how wind force was measured by spinning wind cups and wind socks—some children had seen these at the airport.

23rd

One child wrote about and drew the weather balloon and asked to be told again how it 'measured the wind'. She has asked for help in making a paper windmill so that she can test how strong the wind is and write it down in a book she wants to make. Other children interested in Mary's plan.

24th

Julie arrived this morning and said, 'Miss, my dad says that aeroplane pilots need to know which way the wind is blowing as well as how strong it is.' Together, with Julie and a few more interested children, we went out to look at the weather vane on a nearby steeple—the children are familiar with the words N., S., E., and W. We talked about the position of the sun and noted which way the vane was pointing. Asked the children, 'How can we find which way the wind is blowing in the playground?' They made many suggestions and dashed off to collect materials to try. They decided that their vane had to be 'very light' and they must be able 'to keep it from blowing away'. Many things were tried—feathers, leaves, handkerchiefs, paper, balloons—and after much experimenting and discussion, they decided on a kite-shaped piece of paper attached to a stick by a piece of thread. This they called the 'wind direction indicator'! Later, showed some children a thermometer and pointed out 'blood heat' and 'freezing point' on the scale—they warmed it with their hands and then took it outside, but the movement was so small they soon lost interest.

25th

Started a weather book—the children telling me what to write. Other children now interested and going out to find which way the wind is blowing. The leaves blowing from the trees were noticed, and some of the children have been looking at the little trees in the 'nature tray'.

(The nature tray is a large wooden trough, filled with good loam, in which various seedling trees have been grown from seed. Jam pots of water, sunk into the soil, hold the more temporary collections of flowers, branches, berries, etc. This is a continuing interest as the children push all kinds of things into the soil to see if they will grow, e.g. pips, fruit stones, nuts, etc.)

28th

The children's description of the 'wind direction indicator' was written in the weather book. After the weekend, nuts, berries, and various fruits and seeds have been brought in. Children fascinated by the chestnuts which split open in the warmth, and looked at and touched the inside of their cases. 'It's all furry like our hamster.' I asked them why they thought it was like this.

'To keep the baby nut warm.'
'To stop it hurting itself when it falls down from the tree.'

Many of the seeds have been poked into the soil in the nature tray.

29th

A lovely autumn day—too good to miss—we went to the park. Children collected leaves and fruits blown from the trees, ran about freely over the grass, fed the sparrows, ducks, swans, and seagulls, and commented on the 'large, flat feet' of the water birds—altogether an exhilarating afternoon.

October 1st

Children put their seed collections on the nature tray and talked about the bright colours of the berries and the 'glossiness' of the chestnuts. They touched and blew the 'little bits of fluff' and discovered the tiny seeds attached. They grouped the collection into 'the light ones you can blow', 'the hard shells', 'the soft berries'. While testing the softness of the berries they found the seeds inside the fleshy covering.

2nd

A sheaf of wheat arrived today in preparation for the Harvest Service and because of the children's interest we talked about the work

of the farmer in growing the corn, cutting, and threshing it, and how the grain was ground to make flour for our bread. Michael found a picture of a tractor in a book and copied it with great care and then everyone helped to make a large picture of a farmer at work in the cornfields with his tractor. I said, 'Perhaps we could ask for the wheat sheaf after the Thanksgiving and see if we can make some bread out of it.' In the afternoon John brought a selection of large stones ready for the grinding!

5th

Children rubbed the stones together and found out which would be best for grinding and, incidentally, found that they could make sand with some—others were 'too rough'. They tried crushing things with the stones and eventually decided in favour of some large smooth pebbles which were 'heavy and easy to hold'. Started a book of weather words—e.g. 'A little wind is called a breeze,' 'A big wind is called a gale.' During the discussion one child asked where the puddles had gone and another answered that the wind and sun had dried them up.

6th

Philip, handling things on the nature tray, asked, 'Why have chestnuts got prickles on their outsides—sycamores haven't?' I held some chestnuts and sycamores high up and let them drop and the children commented on the difference in sound and started experimenting themselves. 'I know,' said Philip, 'sycamores don't need prickles, they can float to the ground.' When asked why he thought chestnuts had them, he said 'to stop it hurting itself when it bumps the ground.' Another collection of leaves and berries was brought in by a child who had asked her mother to take her again to the park. She mounted these on a frieze and found names for me to write underneath each one—matching them with the pictures on a chart in *Child Education* (Autumn 1962).

8th

Collected all the children's paintings done since the visit to the park and wrote the story as the children told it.

12th

It was very cold this morning and the children noticed their breath and said they were 'smoking'. We talked about moisture from inside themselves showing on their breath when it touched the cold air outside and I explained that the clouds are 'water vapour' which has met the cold air higher up and 'condensed' too.

13th

Michèle, opening the door, accidentally breathed on the brass door knob and said, 'I've made a cloud on the knob—with water out of me.' Delightedly she showed everyone and then they all went around breathing on things and 'making the water show', e.g. on mirrors, glass, spectacles, drain pipes, car bodies, etc. Later, when talking about their experiments, the children agreed that the water only showed when the material was cold—leaves, paper, clothing, and hands were no use.

14th

Children still breathing on things! I offered 'special' pieces of manilla card so that they could illustrate their discoveries, which they did, and some children asked for help in writing about their experiments. This became very popular and every child became involved. Only one child used the words 'water vapour', none wrote 'condensed'. 'Shiny' and 'silver' appeared frequently in their descriptions and when we talked together they said, 'You need cold things to show the wet and it's better to see if it's shiny.' One child wrote about how clouds are formed.

Preparation for the Harvest Thanksgiving has captured the children's interest—their own contributions have been talking points about how and where the different fruits and vegetables grow, and there has been much handling and appreciation of the beauty of

shape, colour, and texture, as the children polished and arranged the fruits on the platform in the hall.

19th

Children came back to school, after the half term holiday, still talking about the Harvest Festival. They gave the hamster some ears of corn, broken from the sheaf, and watched her select the kernels and fill her pouches full and empty them in her nest. The rabbit was given some straw from the sheaf and nibbled the ends. 'His whiskers are shaking,' said John. The guinea pig hid under his straw bed but betrayed his presence by moving slightly. 'I know he's there,' said David, 'I can hear him shaking his bed up,' and he rubbed bits of straw together so that the other children could hear the 'rustling' sound.

20th

Some goldfish were brought in today and put into the tank we had set up ready for them. All the classroom animals have their own 'book', made, in the first instance, by me, but added to by the children whenever they want to paint, draw, and write about something they have seen or done. One child, looking around, said, 'Oh, the poor goldfish haven't got a book. Can I make one for them?' She took some cards and, sitting down by the tank, made a four-page book about the fish, watching them intently all the while.

23rd

A storm during the night left hailstones still lying about when the children came to school. Great excitement—they collected some and brought them into the classroom, exclaiming how cold they were, and then, that they had 'disappeared into the water'. They made a large mound of hailstones—'It's an ice ball, not a snowball!'—and put it on a dish on the radiator 'to see how long it will last'. They came in from play to tell me that 'the stones have melted, but in the shadow they are still there'.

I asked, 'Why have some of them melted?' 'Because the sun is shining,' they said.

'How does the sun melt the hailstones?' I asked.

One child said, 'It's bright and we can't look at it,' but Eric said, 'No, it's hot, so they melted, like my hand melted them.'

Eric decided to find out how hot it really was outside and fetched the thermometer: he was excited when he discovered that 'the red line is higher than it was before (i.e. before the heating was put on)—and as he took it outside he watched the red line 'get smaller' but was uncertain what this indicated. Two of the children remembered to look at the dish on the radiator and discovered that the lump was now much smaller and was floating in water—'like an iceberg', they said. Some of the children did not know what an iceberg was, so, looking at our miniature one, we talked about ice floes breaking off and being a danger to ships, and David said, 'The sailors can't see the bit under water and they crash and sink.'

26th

Threshing of the corn started today. Children fetched the sheaf from the hall and brought it triumphantly into the classroom. We discussed how we could thresh it. The children tried using their hands at first but soon found that rulers and the longer colour rods were more effective—great enthusiasm and much energy resulted in five jam jars full. Nothing was wasted—all the animals were given fresh straw beds!

28th

The dish that had the hailstones was full to the brim when they had all melted, but today, Linda noticed that the level had gone down and came to tell me, 'I expect,' she said, 'it's made water and gone up to be a cloud.'

29th

Jane, playing in the water bath with a polythene bottle, squeezed out a stream of air bubbles and then produced a jet of water—she brought it over to show me what had happened and when she squeezed the bottle, the air from it moved my hair. 'Look what

I did—I made a wind,' she exclaimed gleefully. She went around the room squeezing the bottle and making 'winds'—a little squeeze made a 'little breeze', a big squeeze made a 'long wind'; she soon found that the wind moved things and she experimented with paper, card, feathers, and ping pong balls and ended up having a game with Julie and David to see who could blow things furthest; Julie made a paper fan and David just blew.

November 2nd

Foggy this morning. Linda said, 'The clouds are touching the ground because it's cold, and I can't see my friend across the yard.'

3rd

Children are fascinated by the feel of the wheat and take handfuls from the jars and let it run through their fingers.

We discussed how we could separate the kernels from their husks. They suggested picking them out by hand and started to do this, standing against my rather high table. As they worked, their breath blew the husks off and they quickly discarded the first method and in no time were using paper fans, and flapping their hands and squeezing the polythene bottles. One boy, turning the model windmill, found that a wind was produced below the vanes, which blew the husks. Husks everywhere! I suggested that they should work outside—a few minutes later David rushed in to tell me that the wind was blowing the husks away.

'Isn't it blowing the kernels too?' I asked.

'No,' he said, 'they must be heavier, of course.'

A jar of kernels was put beside a jar of the mixture (husks and kernels). The children commented on the difference of colour and bulk and compared the weights. I suggested that they might weigh them on the scales and find out what the difference was, but they were more interested in seeing how many kernels they could get from the sheaf—13 oz., eventually.

4th

Class taken over by a student on teaching practice. I plan to work with small groups as the occasion arises.

5th

With a group in another room, the first problem was finding a chair of the right size for each child (this does not arise in the classroom where all the desks are the same size!). Children seemed aware, for the first time, that they are of different sizes: at first the tallest child tried the biggest chair and so on down to the smallest, but, after much experimenting, they realized that it was the length of their legs that made them 'fit' a chair, not their height. This sparked off a general interest in size and we went outside to look around. Children unanimous that the largest thing was the school building, but were undecided about which was the higher, the more distant factory chimney or the ventilation shaft on the school.

David said that if you stood in the road below the factory chimney it reached 'right up to the sky—if we had ladders we could measure them with rulers.'

'No,' said Paul, 'if we could climb to the top we could drop a long rope down to touch the ground and then see which rope is the longest.'

I asked Julie, the tallest child in the group, to walk away from us to the end of the playground. 'She's grown smaller,' they said; and when she returned and had 'grown bigger again', they asked her if she had felt any different! They are still undecided about the ventilator and the chimney; both have loomed large in their paintings.

6th

Some children noticed that the water from the hailstones had all evaporated and that the tin dish was rusty. We talked about things going rusty, and the children told me they had to be wet. I asked how could we have stopped the dish from rusting? 'My dad puts grease on things to stop rust,' said John.

9th

Very cold today—asked a child if she could measure how cold it was. She said, 'Yes' and fetched the thermometer and, with a few other children, took it outside; they came rushing back to tell me that it had been going down as they had carried it. With some help in reading the scale, they duly recorded the outside temperature and then I asked, 'How can we make the red line go up quickly?' They suggested the radiator, put the thermometer on top of it, and watched until it reached 38°C. David wanted to know how the radiator was made hot—he found the connecting pipes and traced them around the classroom. He thought they must be water pipes because they were 'bigger than the electric ones'. I suggested that he turn off the radiator to see what happened. He did this, kept feeling the radiator and comparing the heat with that of the pipes, and later came to tell me that it was cooling down. The caretaker showed him where all the pipes, from all over the school, lead into the boiler house, and he is telling everyone about it!

10th

Again it was very cold and the children wanted to put 'how cold it is' in the weather book. After taking the temperature outside they said, 'Let's see how hot the radiator is today.'

Classroom thermometer not easy for children to see. With one small group we have made our own—of $\frac{1}{3}$ pint milk bottles, lengths of narrow plastic tube, corks, and red ink. Great delight when 'Miss made a fountain', pushing in a cork! These are a great source of interest and children put them in all kinds of places about the school and outside—they know that the movement of the red ink up or down means that the new place is warmer or colder. We made a simple scale on a white card attached to one of the tubes and marked the levels for the coldest and hottest places.

'Why do you think the thermometer ink goes up the tube when it is warm?' I asked.

'Because it's red,' said Linda.

'Because it's liquid,' said Paul.

'Why should a liquid go up the tube when it gets hot?' I persisted.

Linda, eyes gleaming, said, 'Because it wants to evaporate out of the bottle and can't because of the cork, so it goes up the tube and evaporates up and turns into a cloud when it meets the coldness high up in the sky.' And having delivered this, she walked away to the animals, taking Paul with her!

11th

No further interest has been shown in the wheat kernels. Children absorbed in other things—especially the animals—much painting and modelling going on. Told the children I would put the jars in the cupboard until next term when we could plant some of the seeds as the farmers do, and with the rest we could make flour for bread.

13th

Set out to explore the school with a small group—too wet outside. Climbed to the balcony in the junior department to get a better view of the glass roof of the central hall, but children's attention captured by the unusual view of the lights.

'They must be very heavy,' said Neil.

'Why, how can you tell that?' I asked him.

'Well,' he said, 'they're bigger than the classroom lights and in the classroom we've only got wire (flex) to hold them but out here they've got chains and the wire threaded through.'

Coming down I realized that the children were listening to the sound of their feet, first on the wooden stairs and then on the stone steps. They went on with this, testing the sounds on the different kinds of floors—wood floors were 'better' than concrete and the hall floor was better than the classroom floor, although both were made of wood. When asked why, they said 'because it's bigger'. They found three different kinds of wooden floors, with different sounds—one child, very interested in the way these floors are made, became completely absorbed in measuring the length of the boards, using every ruler and colour rod she could lay hands on. In talking

about the sounds with the children, I found they thought it made a difference if the floor was solid—it didn't sound as loud as when it was hollow underneath.

17th

Linda has embarked on a study of the school's lights—drawing and describing a different kind each day; her observation of detail is remarkable.

20th

Stephen cut out a rabbit shape, covered it with material for fur, and then stuck a feather on its nose.

'What's that for?' I enquired.

'So that when he sticks his head out of his burrow he can see which way the wind is blowing.'

Later he cut out a whole family of rabbits.

David said, 'Now you'll have to make a hole in the garden for them to live in.'

They made a small hole in the soil and put some straw in 'so they can have a bed.'

23rd

Karen and Pauline uncovered some of the chestnuts and acorns when moving the leaves in the nature tray, and were excited to see that they were sprouting and called all the other children to come and see them. Later Stephen covered them up again with great care, 'so they won't get hurt.'

28th

Classroom being painted and Christmas to prepare for—this will be the last entry of the term!

Spring Term

January 12th

Class now forty-nine with new admissions. Opened cupboard and some of the new children saw the jars of wheat kernels.

'What are they?' they asked.

Before I could answer, Michael said, 'Wheat seeds—when are we going to make bread?'

'When you have made the flour', I answered.

'How can we do that?' Jane asked, and Michael told her.

13th

Jane arrived with a large shopping bag full of stones she had collected and washed, and another child brought a piece of rock. We found the large smooth pebbles the children had chosen last term and they began to grind the wheat, trying out the different stones, each child making his own selection.

14th

Linda asked to have her pencil sharpened—I was busy at the time and said she could use the pencil sharpener herself if she was very careful. She sharpened her pencil successfully, emptied the bits from the little drawer, took a piece of paper, and made a drawing of the apparatus and wrote an accurate description of it.

18th

Michael painted a picture of the groups of children making flour.

'What's this white stuff up here?' I asked.

'The flour, of course,' he said. 'A lot of the flour went up in the air and on Jane's skirt and jersey.'

20th

Michael reminded me about planting some wheat 'to grow more seeds'. Gave him some pots and he sifted some soil 'to take the stones out' and planted some grain; he has left one pot ready for some pips he is going to bring in.

21st

During story time, Anne, sitting near my feet, reached out an exploratory finger and touched my shoe—stroking it first one way and then the other.

'Your shoe is all covered with little black hairs,' she said.

'Yes, they're made of a special kind of leather called suede,' I told her.

'When I touched it you can see where my fingers went,' she continued.

I took off my shoe so that the other children could see what Anne meant.

Stephen said, 'Your shoe is silk inside.'

Neil commented, 'You've got plastic soles, mine are rubber.'

Then Stephen laughed and said, 'I know all about those heels—they're made of steel and they make holes in the lino and my Mummy's got a pair.'

22nd

Anne came to look at my shoes—'You haven't got your hairy ones on today,' she said, 'these are smooth and shiny (*touching them*)—mine are like that too.'

23rd

A baby guinea pig has been given to the class. Children helped to make a home for him, using a sand tray with wire mesh cover. He is very shy and stays in his box but the children have decided to call him Whistler because the adult guinea pig in the hall whistles, and they say our baby will talk that way too.

28th

Children have taken over the care of the guinea pig. Cleaning, feeding him, and grooming his coat—'He's got brown fur hiding under his black fur,' Julie said.

29th

Michèle, who, up to date, has only wanted to write imaginative stories, took a piece of paper and announced that she was 'making an animal book' and wrote a story about Whistler, his food, and his home.

February 1st

Making water jets with polythene bottles very popular, exploring all the variables—size of bottles, amount of water, and strength of squeeze. Introduced a tin with a hole in the bottom and a piece of rubber tubing and asked if they could make a fountain with it—this they did quite quickly and were delighted to find that they could alter the height of the jet by moving the tin up and down.

3rd

The group playing making jets have evolved a game—corks, pieces of wood, and ping pong balls are floated on the water and pushed under by the force of the water jets.

4th

Fish tanks have been cleaned out and when the fish were put back again Michèle said, 'Please can I mind the fish?' We talked together about the kind of care they needed and she undertook to feed them. She sat beside the tank for some time, watching intently, and then came hurriedly to tell me that the snail 'has made something on the side of the tank.' Looking at the little piece of jelly with a magnifying glass, we discovered that it was full of eggs. How long will they take to hatch? Will they have shells on them? Michèle is quite prepared to wait and see even though it may take a long time.

5th

Children cleaning out the guinea pig cage were very quiet and after a while Christine tip-toed over to tell me that 'Jane has got Whistler on her knee.' I glanced over and saw Jane stroking him very gently. A short time later Christine came again. 'Please tell the children to be quiet,' she asked. 'Whistler's just gone to sleep.'

Without much thought, I said, 'What a funny time for him to go to sleep—he should sleep at night in his bed!' and Christine explained: 'Well, you see, he's only a baby, and our baby goes to sleep in the daytime when my mummy nurses him on her lap.'

8th

A sudden hush in the classroom. I glanced up and heard what the children had stopped to listen to—Whistler trying out his voice for the first time in our hearing and to the children's delight 'whistling'. Later on, Jane came to find me.

'I'm always going to bring carrots for Whistler,' she said conversationally.

'Oh, why?' I asked.

'Because he likes them better than apples or tomatoes or cabbage or anything else.'

'How do you know?'

'I watched him on Thursday and Friday and today and every time he eats the carrots first—at the end where the leaves grow.' Catherine said, 'Isn't it funny? He eats his favourite food first, but I always save the best till last.'

12th
Great interest in the nature tray as more and more seeds germinate. Apple pips have 'got their hats on' but David decided that 'the root's so strong it's pushed the seed up into the air.'

17th
Children have planted peanuts, birdseed, walnuts, and lemon and grape pips all in a row to see if the seeds 'will have a race'. Because the orange pips they planted before Christmas have only just started to grow, the children think that the lemon pips will be the slowest.

March 3rd
Deep snow in drifts—children very thrilled—some busy pressing handfuls of snow to make snowballs, others fascinated by its softness, sinking their hands into the drifts and lifting it gently so as not to disturb it.

Kevin, in new wellingtons, said, 'My new boots have got a pattern underneath and they make a pattern in the snow'.

His twin, Stephen, said, 'Mine didn't—but mine are smooth.'

'Didn't you make any footmarks at all?' I asked.

'Yes, he did,' said Kevin, 'and the snow went all grey down at the bottom of the hole where his foot was.'

Another boy, also called Stephen, said he had seen birds' footmarks, 'but they didn't make holes.'

'I wonder why?' I said.

'Because they were too little and not heavy, I suppose,' he said.

We talked together about weight and sinking into the snow and the children went off to look for things that would sink and things that would 'just make marks'.

4th
The twins, Kevin and Stephen, reported that their cat made footmarks but did not make holes in the snow, but the next door dog 'had gone right in—but he's much bigger and heavier.'

10th
Some children still making fountains—they are now estimating the force needed to make the water jets go to a pre-arranged height.

12th
Jane, looking at the growing peanuts, said, 'Oh, look—peanut shoots!'

'No, they're not,' said Paul, 'that's the root—it always comes first.'

'Why?' asked Julie.

'Because it needs to drink to grow, and the root's like a straw,' he explained.

15th
John said, 'I think feathers must float.'

'Have you tried?' I asked.

'No,' he said, 'but ducks and seagulls and swans float and they've got feathers,' and, taking a feather from the weighing table, he went off to float it.

16th
Jacqueline, watching a snail in the fish tank, was distressed because she thought it was coming right out of the shell. We watched it together for a little while and then she said: 'Oh no—it's all right—he's walking along and pulling his shell behind him.'

17th
Linda, who has had a long absence through illness, has become very interested in the classroom chairs, some of which are very old and falling apart. She has been watching the caretaker repairing them and today has written a story about them, with illustrations.

25th
Michèle's snail's eggs have hatched today and she now knows the answer to her questions. Julie tried to count them but gave up after a

while because 'some of them are so small they look like bits of gravel and I can't tell the difference until they move and that would take too long!'

30th

We walked again in the park. Alder catkins and the pairs of mallards captured the children's interest. As we skirted the boating lake, Paul drew our attention to the flotsam in one corner. 'That's been blown there by the wind,' he said. John said, 'There's all sorts of stuff there—leaves, branches, orange peel, apple cores, paper, and I can see a feather too.'

31st

Children made a large collage picture story of the walk in the park—the ducks take pride of place and they have numbered the pairs!

April 8th

Wheat growing well—Michael reminded me again about making bread, so we are planning to have an end of term tea party and make everything for it.

13th

Children all involved in preparations. Butter was 'churned' today and much energy expended in shaking the milk and the cream together.

'Look, the butter is floating,' said Jane. Catherine tasted it and said it wasn't like shop butter, but she couldn't decide what was missing. I suggested that she add a little salt, and after stirring it in she tasted it again and approved. Cheese was made from sour milk which the children squeezed through a cloth—they were amazed how little cheese came from a lot of sour milk.

14th

The day we made bread rolls from our own flour! Children weighed and measured ingredients and were fascinated by the smell of the yeast and the rising of the dough on the radiator.

In the afternoon we had our tea party, at tables made gay with Easter baskets which the children arranged. We ate our rolls, home-made butter, cheese, and home-grown cress. Afterwards, several children asked for the 'bread' book so that they could write up the party and bread-making stories. As it was the last afternoon of the term we had time for only two stories!

4 *Spirals and natural dyes*

Class	**Second year in preparatory department of a grammar school. 5-6 years. Full range of ability**
Class number School roll	30 girls 469
Term	Autumn
Building	Extension to converted dwelling house.
Classroom	Roomy, airy, and well lit.
School environment	Suburb of a large city in good residential area. School set in its own grounds.
Local setting	Northern Ireland; an industrial city. Immediate surroundings built up, but open spaces available.

At the beginning of the term the pupils put together the shells and stones they had collected during the holidays. These were handled, sorted into groups, pressed into clay to make patterns, and dipped into water to make the colours brighter. The pupils held the larger shells to their ears to hear the sound.

The arrival of an excavator led them to visit the site where the ground was being prepared for building a new school extension. What they found there led to discussions on roots, rocks and pebbles, animals underground, and things we use which come from the earth. After visits to the site, and the ensuing discussions, the children did a great deal of painting.

During their visits to the earthworks, the children collected leaves. They cut out leaf shapes and coloured them. At about the same time, a garden cross spider was kept in a large tank and although this was looked at and commented on, it did not spark off an interest in spiders' webs.

Much later in the term, when a spider built a web in a corner of the classroom, the children became interested in spirals and this, in turn, started them collecting all kinds of spirals: shells, springs, tendrils of plants, screws, and even a stick of barley sugar. Some of these are shown in figure 4.

The teacher showed the children how to draw spirals using a stick and a piece of rope with a pencil at the end. They cut out these large-scale spirals with scissors and immediately saw them as snakes, which they painted in a great variety of colours. The teacher added a book on snakes to the class library and the children referred to this for information about colours. A slow-worm brought in by a visitor was watched closely, but only a few pupils would handle it.

FIG. 4. A collection of spirals.

Spiralled tinfoil Christmas decorations were seen to twist as they hung and there was much discussion as to the reason.

The children made clay models of spirals and this work developed rapidly when a child reported having seen a TV programme in which coil pots were made.

For more than four weeks colour provided a main theme for activities and discussion. It began when commercial dyes were used to colour a collection of old socks for making puppets. This led to a discussion about dyeing and where dyes come from, and nobody had ideas to offer.

The blackberry season had begun and the next day, when the children brought blackberries into the classroom, they soon found that their hands were stained purple. This gave them their first clue about vegetable dyes.

They tried rubbing the berries on paper but could not get much juice: 'How do you get juice from blackberries?' someone asked. Harriet said: 'Mummy boils them and puts them in a bag, and the juice drips.'

This idea started them off, and the following day Janet brought a book on dyes from home.* In it they found many familiar plants named: elderberry, onion, dandelion, and marigold, to which they added beetroot and tea.

The dyeing technique was a simple one. The plant material was boiled and strained, and pieces of material dipped into the liquid. 'Does it matter how long the material is in the dye?' a child asked. An egg timer was produced and the materials dyed were marked 'One egg timer', 'Two egg timers'. They were soon seen to become darker the longer they were left in the dye.

*Thurstan, V. (1930) *The Use of Vegetable Dyes.* Revised edition. Dryad.

While this was going on, some of the pupils began counting the colours in the paint boxes. At the teacher's suggestion they painted a large square with each colour, pinned these to the wall, and labelled them. Then they began asking questions.

'Which colour do you like best?'
'Which colour of flower?'
'What colours can you see out of doors?'

They mentioned autumn colours, and then said:

'The sky is sometimes a lovely pink.'
'I've seen a red sky.'
'It's grey on a rainy day.'
'Sometimes it's black.'
'Once I saw a rainbow.'

Deirdre then silenced everybody by declaring that she had a rainbow. At first this was received with scorn, but she stuck to her claim and promised to bring the rainbow next day. When it arrived it proved to be a piece of chandelier which acted as a prism, and there was an outburst of enthusiasm for making and painting rainbows. One picture can be seen in plate 2. The teacher then asked where else they could find rainbow colours and they found them in bubbles, oil on water, and bevelled mirrors, and noticed a connection between sunlight and colour.

The children also became keen on mixing water colours, and did this on a white plastic draining tray. They found that red, yellow, and blue alone would produce shades.

Presently, too, the teacher brought in some coloured gelatine sheets. The children let them overlap and held them up to the light. They found that torch light, shining through a coloured filter onto coloured felt, also produced colour changes.

They were encouraged to use water paints on window panes. This was popular on sunny days.

Finally, they wrote the names of the colours on the display board on cards and made a game of reading them. They learned some twenty-four words in this way. They also wrote down comments and collected them for 'Our Book of Colours'.

Very lively discussion accompanied all the work, and the children particularly enjoyed talking about their discoveries.

During the experiments with vegetable dyes, the pupils' interest in the egg timer made some of them wonder about ways of measuring time. This was not of such general interest as colour and spirals, but eleven children made active enquiries and gained some appreciation of time as a measurable quantity.

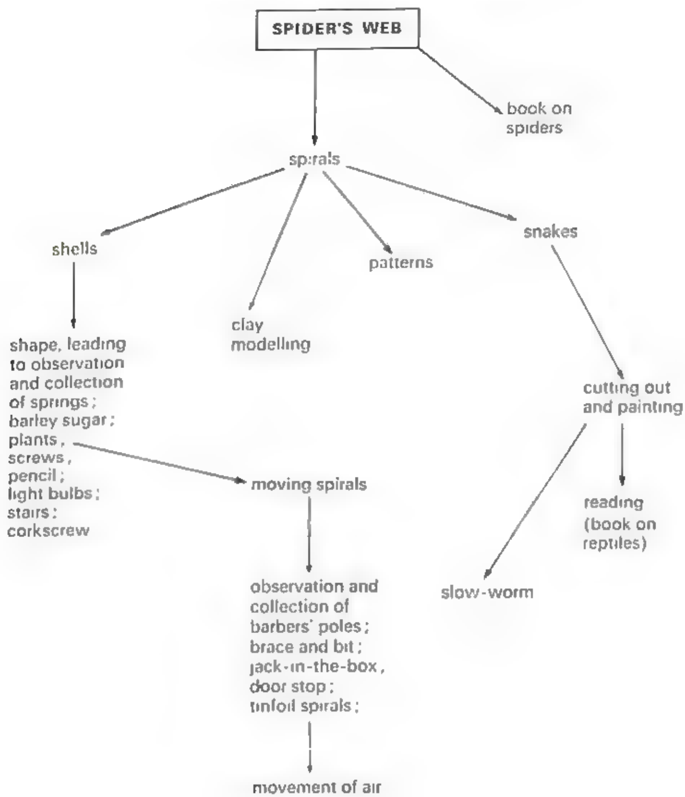
A stopclock was available in the classroom and the children used it to time:

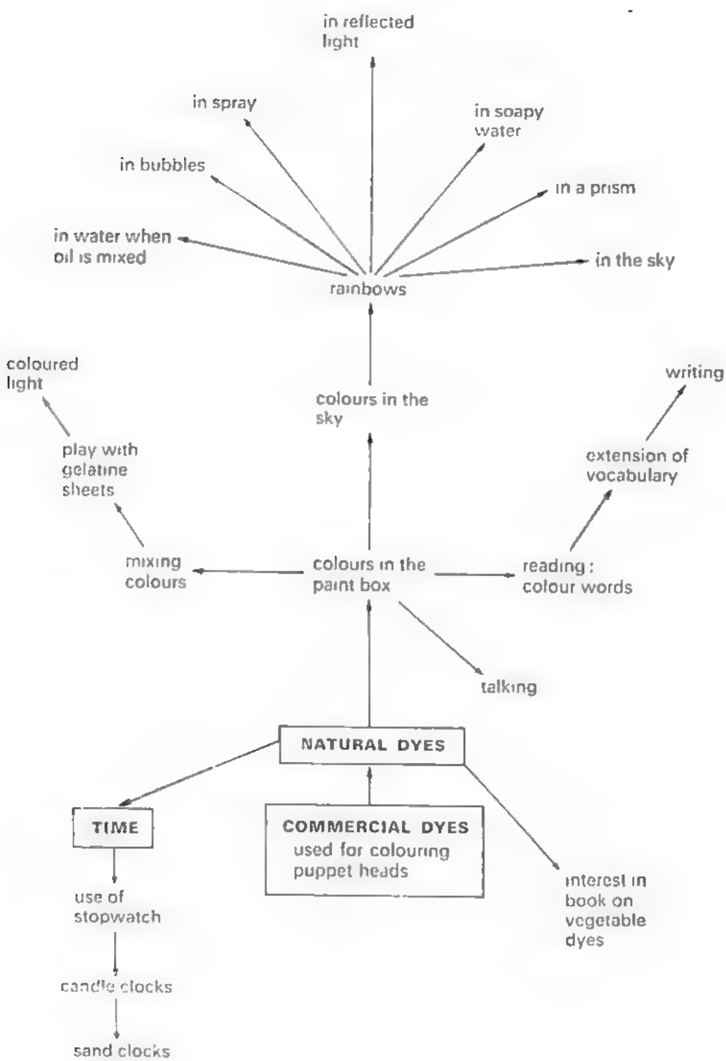
1 an egg timer
2 the hamster climbing down a slope
3 a ball-bearing rolling down a slope
4 themselves doing puzzles
5 a cake candle burning out

The work with candles developed into an interesting series of activities.

The children burned rows of candles for one, two, three, four, and five minutes, and noted their diminishing lengths. They made candle clocks with small ones showing minutes and large ones hours. They also developed an interest in clock faces, and many looked to see how minutes and hours were marked. Some of them made clock faces from cheese boxes and others played a game, showing in mime what they would be doing at various times of the day.

This is an outline of some of many developments from a few starting points, chosen from many which occurred in the day to day life of this class of six- and seven-year-olds. A wealth of material was provided in the classroom for the children to handle, play with, use, and talk about; they were also free to explore and use collections of bits and pieces readily accessible on low tables and improvised display stands around the perimeter of the hall which has already been described and illustrated in *Teacher's Guide 1*, in the final section of Chapter 5.


SPIDER'S WEB
book on spiders
spirals
shells
patterns
snakes
clay modelling
shape, leading to observation and collection of springs; barley sugar; plants, screws, pencil; light bulbs; stairs; corkscrew
moving spirals
cutting out and painting
reading (book on reptiles)
slow-worm
observation and collection of barbers' poles; brace and bit; jack-in-the-box, door stop; tinfoil spirals;
movement of air


in reflected light
in spray
in soapy water
in bubbles
in a prism
in water when oil is mixed
in the sky
rainbows
coloured light
writing
colours in the sky
play with gelatine sheets
extension of vocabulary
mixing colours
colours in the paint box
reading: colour words
talking
NATURAL DYES
TIME
COMMERCIAL DYES used for colouring puppet heads
interest in book on vegetable dyes
use of stopwatch
candle clocks
sand clocks

5 Bones

Class	Vertical streaming, 6-7 years. Full range of ability
Class number School roll	41 boys and girls. 240
Term	Spring
Building	1964. One-storey brick building of modern design. No corridors—two communicating classrooms lead off from three corners of a large, square, all-purpose hall.
Classroom	Pleasant. Windows along two sides, with low working bench beneath and storage lockers below it. Cloakroom alcove, toilets, sink, low trough and wash basins with hot and cold water, and storeroom. Small vestibule with woodwork bench and table for growing plants and door leading into playground.
School environment	Surrounded by large open grass areas, playgrounds, and playing field (shared with junior school on same site).
Local setting	School was built to meet the needs of a new housing estate providing for a population moving out from slum clearance areas of a large industrial city in north-west England. The estate borders on a green belt of open farming country.

Bones

Children's interests tend to wax and wane, but often an individual child, or a small group, will hold onto a particular interest, and, even after a lapse of time, will pounce on anything relevant to it that crops up and forge a new link in the chain of his experience. This was true in the case of the work on bones, which began with examining a few chicken bones after Christmas, and reached a peak, some months later, with the construction of a life-size model of a human skeleton. It was a certain individual and sustained interest on the part of one or two children which 'carried' a group on to making this.

The chicken bones were put on a tray in the hall by the headmistress, soon after the beginning of the spring term. They were joined by contributions brought in by the children, teachers, and domestic staff, and the collection grew rapidly. It included breast and wish bones of duck and chicken and various leg bones; the rib cage and shoulder blades of rabbit; parts of Sunday joints: shoulder of lamb; knuckle joint; ham shank,

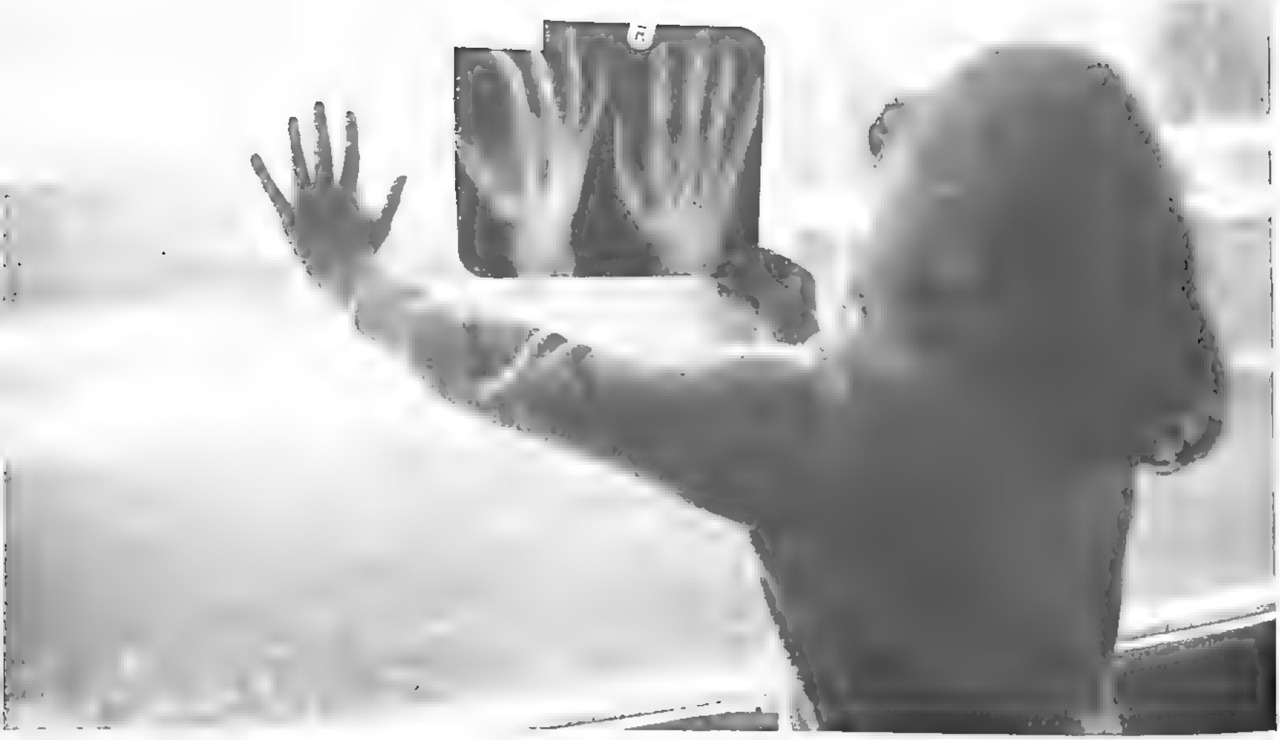


FIG. 5. Comparing a live hand with an X-ray.

FIG. 6. Daniel and his wooden man.

etc.; and a beautifully cleaned sheep's head, complete with lower jaw.

The 'bone tray' became a focal point and groups of children were continually handling the different bones, trying to identify them, fitting parts together, and gaining much experience. They searched in books for pictures of skeletons of all kinds, including those of prehistoric animals. Mounted skeletons of a pigeon, rabbit, and snake were borrowed from a college and left beside the tray and the children found where the individual bones fitted in. They were amazed at the 'thinness' of the bird skeleton. Before Christmas they had been very interested in watching the behaviour of the different birds that came to their bird table, and in particular they had been impressed by the span of gulls' wings, and the size of a rook at close quarters, saying, 'he looks too fat to fly.' A good deal of experimenting had followed, with feathers, birds' wings, and heavy and light things, to find out which would float down and which fell straight down.

Their experiences with feathers led the children to conclude that as the bird skeleton was so 'thin', it needed a lot of feathers to make it fat, but as feathers were so light they did not make the bird too heavy to fly.

They enjoyed comparing the sizes of the bones and started to measure them. The shin bone of the cow felt very heavy, and Susan suggested weighing it. They did this (it was 3 lb. 12 oz.) and then Susan said, 'Let's weigh the leg bone of the chicken.' It was 3 oz.

The teacher suggested that they might write down what they had found out and put it by the bone tray so that other people could read it, and thus the children started their 'Book of Bones'. In this they made drawings of the bones that interested them—and one child made a drawing of the complete skeleton of the rabbit. They also stuck in pictures they had found and wrote about these.

Some fresh bones, obtained from the butcher, gave the children the opportunity to explore the way in which a joint works and they looked at and touched the wet, shiny, satin-smooth articulating surfaces.

When Daniel brought his pet rabbit to school for the day, the mounted skeleton was taken into the classroom and the children gently felt the living animal, locating the positions of the bones and joints.

(This identification of 'dead' bones with the living animal was felt to be important. Two five-year-olds had been overheard talking about ghosts when creeping past the bone tray; they were drawn into conversation, and were soon feeling their own bones inside themselves.)

Some X-ray plates of various parts of the human skeleton were placed in a pocket near the tray and excited immediate interest. The children held them up to the light or against the windows, as you can see in figure 5. They identified the parts by exploring their own bodies and those of their friends, feeling, moving, bending, and demonstrating to each other.

The teacher developed this interest when the children were dancing and moving freely, by helping them to realize more of the ways in which their bodies could move. Rods and sticks were used by the children and arranged to form 'stick men'. At first these had unjointed 'limbs', but later two rods were used to produce 'joints'. When a sack of off-cuts of wood was taken into the classroom and tipped on to the floor, different children were attracted by different shapes and pieces, and much discussion went on about the things they were going to make. For example, 'I'm going to make a bow and arrow,' one child said. 'Don't be silly—that piece won't bend,' said another. Daniel started to march around holding his body as stiff as a ramrod and chanting, 'I'm going to make a wooden man.' This he did (see figure 6), showing great ingenuity in attaching the head to the body. When it was finished, complete with a tuft of sheep's wool for hair, Daniel's little man became his shadow and was never far away!

At a much later date, when the caretaker brought along some long cardboard tubes after unpacking some stock, some of the

children pounced on them and immediately began to lay them out on the hall floor in the shape of a body. After commenting amongst themselves, they cut up the longer tubes into halves, thus giving each limb an upper and lower 'bone'. In discussing what they could use for the spine (a tube would not bend), they considered large beads threaded on string, but Stephen pointed out that the vertebrae should vary in size. He was given a box of oddments and selected five cotton reels as a beginning. He went on searching about the school and finally collected what he wanted, and threaded the reels and beads in graded sizes on to a length of flex. Heather and Christine decided that they could make the skull, using egg cartons made into papier-mâché and moulded on a basin. The children were now thinking of their skeleton in three dimensions, rather than as something flat laid on the floor. The P.E. rubber balls were pressed into use as ball joints, but were found to be too big. Some ping-pong balls were then put out and the children soon adopted them as being a better size.

At first, the lower part of each limb consisted of one tube, but after some discussion with the teacher and thoroughly feeling their own limbs and referring to the X-rays and books, the children were sure that there should be two bones. They tried putting two pieces of tube together but were not satisfied, and after hunting for something smaller, eventually made tubes of the right size by rolling lengths of thin card and sticking it with Sellotape. They tried to make the hands and feet in paper, but were not very successful. Then some plastic hair curlers were put into the 'odd' box, and were soon seized upon by the girls, who made an excellent job of contriving jointed hands and feet by cutting the curlers into lengths and 'jointing' them together with fine wire. You can see the result in figure 7.

When the children first constructed the skull, they painted the lower jaw onto it, so that it could not move, but after talking about it and looking at the sheep's head in the bones tray, they made a separate jaw and hinged it on to the skull. Figure 8 shows how.

Next, the boys thought out the rib cage and made it of thick wire, attached to a cardboard breastbone in front and around the cotton reel spine at the back. The 'floating' ribs were seen on X-ray plates and intrigued the children.

Much pleasure was gained from this work and much estimation and concentration were demanded by the task which the children set themselves. In the end, they could make their skeleton 'do the twist', sit, stand, bend, and perform the general movements which they themselves could make.

A broken electric light bulb

One dull morning the classroom lights were on, and some of the children noticed that one of the bulbs was not lit. The teacher remarked that it looked all right and that the glass was not broken, but William said, 'The wire inside is broken', and Ian added, 'The electric can't get through'. That afternoon Alan brought an old electric light bulb to school and as the glass was clear everyone could see the broken wire inside. The teacher put out some small torch bulbs, wires, and batteries, and before long, four of the boys were experimenting and trying to get a bulb to light. They worked with great concentration and perseverance for an hour before they were successful. Stephen said, 'There are two wireholders in the battery so we must have to use two wires.' Until then they had tried the wires singly.

After listening to a story about a lighthouse which the teacher read to the class, Robert and Stephen found a long narrow box and said they wanted to make one. 'Can we make it real and put a light in it?' Work on this went ahead quickly and a bulb was put at the top and connected to a battery below. Malcolm, who had joined Robert and Stephen, brought a holder for the bulb from home.

Philip, watching operations, said, 'In the story the light went round.'

TEACHER: How can we make it go round?

FIG. 7. Giving the skeleton toes made of hair rollers.

FIG. 8. The skull has a movable jaw.

ROBERT: If we put the bulb on a little wheel this will go round.

In the waste material box they found some empty cine spools.

STEPHEN: If we can make the little wheel turn, the light will go round.
PHILIP: When we've put windows in we can't get our hands inside them, so we can't make it turn.

Freddie came over to join the other boys and said:

'If we put string round two wheels like the bicycle wheels in the hall, we could turn the bottom one and then the light would turn too.'

The group worked on this problem for a time, meeting considerable difficulty in fitting a belt system into the tall narrow shape of their lighthouse, only to discover that it wouldn't work because the top wheel had to move horizontally. At this point Robert said, 'Let's pretend it's turning.'

(Although many kinds of cog wheels were in the trays in the hall, these children had not yet had *sufficient* experience in using them to be able to apply it to their problem.)

PHILIP: Can we put glass round the top?
STEPHEN: Don't be silly, it would cut our hands.
TEACHER: Can we find something that looks like glass?
ROBERT: We can put plastic round like we put the clay in.
PHILIP: Oh yes, the light will shine through that.
Keith knew the word:
'It's transparent.'
TEACHER: Can you think of anything else that's transparent?
ANN: Water—when it's in a glass jar we can see right through it.
NEIL: Milk is in a glass bottle, but I can't see through that—the milk is thick.

The children fixed some pieces of red and clear Cellophane around the top. After this, they went off in search of stones 'for rocks in the sea around the lighthouse.'

They brought some pebbles from the nature table. 'They're lovely and smooth,' said Philip. 'The stones I found in the yard are rough,' said Neil, and Edward commented, 'The pebbles came from the sea, the sea makes them smooth—the waves are always washing them.' Neil became very interested in the stones—handling them to feel the different textures. He started to make his own 'Book about Rocks', searching through magazines and B.B.C. leaflets for pictures and writing about what he found out.

When next the children were mixing paint in jam jars, Daniel said, 'I can still see through it a bit.' The children compared each other's jars as they added more powder and at last Keith said, 'Mine is thicker than milk now—I can't see through it at all.'

The lighthouse figured in the children's paintings and some of them made the beautiful collage picture shown in plate 3.

The problem of wheels and moving belts arose again later, when a number of the children were involved in making a model of a local big store. Much discussion, preparation, and planning had taken place before the towering five-storey block was erected in a corner of the hall just outside the classroom. They had to solve the problem of supporting the structure so that each of the floors could be left open on two sides 'to make it easier to put things in and to see into it.' They fixed a long cardboard tube to act as a supporting pillar for the open corner. The next problem was 'making the stairs that move'. George found some corrugated cardboard. 'Can we use this?' he asked, 'it looks like little steps.' They cut the cardboard into narrow strips. 'We'll put it on bobbins,' said Malcolm. They made the staircase for each floor separately at first, and stuck the bobbins to walls. 'Now we can't turn them round if they're stuck,' said Ian.

While the boys were puzzling over this the headmistress arranged to take a small group to visit the store. Malcolm especially noticed the escalators. 'They cross each other on

each floor,' he said. 'If we make our cardboard go zigzag it will move.' The teacher suggested that they should try it out with a separate model on a small scale so that they would not be hampered by the big model. George, remembering how they had joined the bicycle wheels in the hall with a belt, said, 'We can put a small bobbin here, and this tin lid at the top so when we turn the bobbin the cardboard will move over the tin lid.'

'We can't stick the bobbin or the tin lid to the cardboard walls,' said Malcolm.

'No, we'll knock a nail through the middle of the lid and put a little piece of wood through a hole in the wall and then through the bobbin.'

Eventually they achieved movement of the corrugated strip when they turned the bobbin.

Ian said, 'Now we can make a big moving stair and put it in the store.' They did this with a long continuous strip of corrugated paper revolving on two simple wheels. Malcolm made sure that it went zigzag from one floor to the next. However, when it was finished they still could not get it to move freely. 'The piece is too long,' suggested George. 'I think if we had shiny paper it would slip better,' said Malcolm. Patiently and carefully they dismantled their staircase.

At this point in time Christmas activities took over but they returned to their problem again after the holiday with new zest. They decided that the ridges of the corrugated paper had stopped it from gliding over the rollers. Kenneth suggested that they could use a long piece of leather like his mother had on her sewing machine but although a search was made none was to be found. Malcolm said, 'Let's use tape—my Mum's got a long roll of tape.'

Next day he brought the tape to school. They worked out the zigzagging of the up and down escalators as they had done before but they decided to put in stronger rollers at the top and the bottom. Anne said, 'We will have to mark the tape with black lines to make it look like steps.' She undertook to do this laborious task and used a thin paint brush but discovered that however thinly she drew the line 'it went smudgy' and the paint ran along the cotton fibres in the tape. She asked if she could borrow the teacher's felt pen and was satisfied with the line it made. When all was ready and the tape was mounted on the rollers Malcolm carefully pulled at the bottom of the tape and the whole 'belt' moved slowly. The children crowded out of the classroom as soon as they heard it was working and there was great excitement. 'We can't move it too much,' Malcolm informed them, 'because it's only cardboard and we don't want to collapse it.' The children accepted this and everyone seemed satisfied with the result.

A flannelgraph

A student taking the class used a flannelgraph to illustrate a scripture story. It was with some difficulty that she finished the story because the children were so fascinated by the flannelgraph and full of questions about how it worked:

'What makes it stick?'
'Is there paste on it?'
'Why don't you use Sellotape?'

The teacher, aware of the possibilities of this kind of situation, put out a collection of materials with different kinds of surfaces—coarse, fine, rough, ridged, hairy, fluffy, smooth, etc. Some of the children, handling them, found that lint 'sticks to itself'. Donald wanted to know if the tiny hairs helped it to do this. He tried a smooth piece with the lint but could not get it to stick—'Two shiny pieces will stick, though,' he said.

Susan, summing up, said: 'The two materials that are the same stick together—the shiny pieces and the fluffy lint pieces stick together.'

Next, Susan stretched a piece of elastic and then tried to do the same with a piece of tweed.

'That won't stretch,' Stanley said, 'it's got no rubber in it.'

Susan said: 'If I cut a long thin piece it will stretch a bit.' She did this and showed Stanley, who got a tape measure to see how much it had stretched. Together they worked

out how much more the elastic stretched than the tweed and the result was six times. Susan and Edward started to make patterns using the different materials they had been handling.

Philip and Malcolm found that pieces of wet polystyrene stuck together. Malcolm tried joining two dry pieces but however hard he pressed they separated. 'The water must be like paste,' he said, and went on to see how many wet layers would stick together. Later he showed his teacher seven pieces of wet card stuck together. 'You have to press all the air out,' he commented.

Gillian brought some burdocks to school and they all started sticking them onto each other!

> TEACHER: What makes them stick?
> DANIEL: They've got sticky stuff on them, like paste.
> TEACHER: Try sticking them onto some paper.

From trying them on their clothing the children now experimented with many different kinds of surfaces, finally deciding that 'hairy or fluffy surfaces are best', and that they would not stick to smooth things.

> FREDDIE: They must stick on to the hairs of our jumpers.
> TEACHER: I wonder how they can do that?
> STANLEY: Let's get the magnifying glass.

This interest in materials that stick started some children experimenting with the consistency of paste. They found when it was too watery or too thick, that it stuck at first, but came unstuck when it dried. In testing the sticking power of the paste they used scrap card and pictures and eventually the paste became coloured.

> RONALD: Look at this paste, it's blue, I'll paint with it.
> ALAN: You can't put a paint brush in it, because it's really paste.
> RONALD: Well, I'm not painting with a brush, I'm using my finger.

This idea caught on and the children loved using the thick medium and making it stand out on the paper. Some exciting paintings and patterns resulted.

6 *Day-old chicks*

Class	**6-7 years. Full range of ability**
Class number School roll	28 boys and girls 180
Term	Summer
Building	Attractive prefabricated cedarwood construction. Late 1950s.
Classroom	Pleasant and airy. Plenty of room for display. Sink. French windows leading to lawns.
School environment	Set in corner of scrub land on fringe of large council housing estate.
Local setting	Midlands. A city specializing in light industries.

The children were excited to hear from the headmistress that they had been promised a dozen chicks by a local dealer.

Using materials and instructions provided by a handicraft instructor in a nearby college of education the headmistress, class teacher, and several children built a cage in which the birds could be kept.

There was the expected buzz of excitement when the birds arrived. The children handled them a lot and discussed them frequently, and at length. In particular, they were intrigued by the helplessness of human infants, compared with the chicks; an idea which arose because one of the children talked about his newborn baby brother. Many suggestions were put forward to account for this helplessness, ranging from lack of strength and inability to balance, to the absence of the same need to search for food.

One of the children had previously read about the egg tooth on the beak and immediately began to look for it. Once discovered, this became a continual source of interest throughout the next few weeks.

The children were used to weighing anything new, and it seemed a natural thing for them to weigh the chicks. One child took on the duty of weighing, and they kept a daily record. Each day, this boy prepared the scales and tried to estimate what the weight would be. Then he collected the weights and tested the accuracy of his estimate.

At an early stage, Claire announced that she would write a book. After some thought, she decided that to write about the whole chicken would be too much, and finally settled for a book about its head. She studied the head carefully each day. Other children took up the idea, and made studies of the chickens' wings, feet, tails, and so on.

Although the chickens remained a prime

focus in the classroom, other lines of enquiry started at this point. As usual, the children increased their vocabulary greatly and refined it. Some of them wrote, and some of them put their writing to music. They did this with the aid of a class xylophone, the children inventing a tune and the teacher writing down the notation for them. They copied this musical notation, together with their poems, into their books.

Some of the children kept a careful watch on the growth of the chickens and the changes in appearance which accompanied it. Others turned their attention to the bird table outside the classroom and began to study the birds of the locality.

For instance, they noticed that dry days brought many sparrows and wet days meant starlings. One child asked what the starlings were pecking for in the ground, and on the first wet day, the whole class donned raincoats and went outside to find out. There they saw the starlings eating worms. They began to wonder if only worms were being eaten and they dug up a block of soil to see what else the starlings might be seeking. A group of children carefully examined the soil. They were excited to find a number of seeds and tried to germinate them.

This variation of bird populations with weather conditions proved particularly interesting to one particular boy. He sat at the window for an hour each day for a week and recorded the numbers of different birds visiting the table. This was a remarkable piece of concentration in one so young, and is an example of the perseverance which young children often show when the interest is sufficiently high and the motivation strong.

The interest in birds feeding led one girl to bring a packet of a proprietary bird food to school. She and her friends read on the packet that the food contained ten ingredients, so they settled down and sorted the contents. They could only find nine and subsequently wrote to the manufacturers, listing their findings and asking what was the mysterious tenth ingredient.

One outcome was that the girls wondered if birds had a preference for any particular ingredient. Their teacher discussed with them how they might find out and they suggested putting the different materials in light metal plates on the bird table. When they were asked how they would know how much had been eaten, they said they would count the bits, but their teacher drew their attention to some constituents which were almost powders. After a little thought, one of them said she would weigh them.

There was some difficulty as the wind repeatedly blew the plates off the bird table. One girl thought that the wind was getting under the flanged edges of the plates and lifting them. She suggested using flat tin lids instead of plates, and from then on there was no trouble.

Those children who were examining the soil had found tiny earthworms in cocoons, which the children referred to as eggs, and the teacher followed this up by asking what other things came from eggs besides chickens and worms. The children's suggestions included ants (there was an abortive attempt to build a formicarium), fishes, frogs, and reptiles. The final suggestion caused the headmistress to bring a tortoise to school.

The tortoise became a new, exciting centre of interest. The children weighed it, examined it, and measured it. They timed its movements, and then used it as a model for painting, needlework, clay models, and collage.

Eventually, they tied string around its shell and fastened the other end to a shoe box, leaving the animal to graze on the lawn outside. The box was not heavy, and when the tortoise dragged it along, one girl put some stones in it. A boy now wondered how much the tortoise could pull and the stones were replaced with weights. The teacher asked if they thought it would pull more or less on the wooden floor of the classroom and on the polished floor of the school hall. There was great surprise when it could not pull more because its feet slipped on the shiny surface.

Some of the children wanted to measure the thickness of the tortoise's shell but found great difficulty. After discussing the problem

PLATE 1. Hamster, by a five-year-old (p. 22).

PLATE 2. Picture of the spectrum (p. 36).

with the class, the teacher decided it would be valuable to set up a display of things used in measuring. One of the instruments displayed was a motor car speedometer, and this prompted a group of children to study vehicles in which human beings move themselves about.

Meanwhile, the chickens and other birds had not been forgotten. One child brought to school a deserted bird's nest, and a group of them took this apart and made an attempt to reconstruct it. Other children collected feathers which they examined under the microscope. They were interested in the tiny barbs they saw there and the feather's appearance became the basis of pattern building.

'Why does a bird have wings?' asked one child, and the teacher followed this up by adding suitable books to the class collection.

One boy had heard that birds put their feet forward when they landed and wondered if it was true. He spent a great deal of time at the window observing.

Eventually, a child raised the topic of bird migration and the teacher added to the collection a few books about Africa.

7 Electricity

Class	6-7 years. Full range of ability
Class number School roll	35 boys and girls 280
Term	Spring
Building	An old country house set by a spinney, with modern buildings spreading from the original structure.
Classroom	A large, well-equipped, airy room with windows on two sides Free-standing vertical display panels are arranged to form areas of interest.
School environment	Large playing area with the spinney fringing two sides of the old house. Set within the heart of a large post-war council housing estate.
Local setting	Midlands. About three miles from the centre of a wealthy city with light industries.

One of the articles on the discovery table in the classroom was a small torch which the children used for flashing and shadow-making. One day, Raymond announced that he had made a torch at home but not like the one on the discovery table. In fact, it consisted of a small battery, a bulb, and a short piece of wire.

Because Raymond was concerned about the life of the battery, he refused to let his classmates use it, so the teacher supplied lengths of wire of different thicknesses and metals, half a dozen bulbs (1·5 V to 3·5 V) and three batteries (1·5 V, 3 V, and 4·5 V).

After much discussion, several children became involved, until about two-thirds of the class could produce a light using the 3 V and 4·5 V batteries. These batteries had two metal tongues to which wires could be connected, but the 1·5 V cylindrical single-cell unit was more difficult, for it had only one obvious terminal, the brass knob on the top. Where should the other wire be placed? It was placed on the blue cardboard cover, then the red coloured part, and eventually on the base. This produced a light, 'because it is metal.'

From then on, the cylindrical battery became the favourite because it could be stood upright on the end of the wire and one hand was then free to manipulate other things.

By now, many children were working on individual problems concerned with the electricity materials, and the teacher added fresh supplies of basic materials to the discovery table. Much of the exploration did

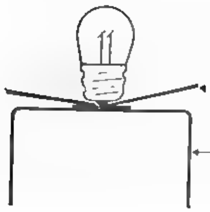


FIG. 9. This failure taught Martin that you need two connections.

not produce positive results. For instance, Martin trapped a piece of wire between the battery terminal and the bulb, as in figure 9, and there was no light.

To him this was of great significance and he showed several other children how they could repeat it.

Trevor worked with a multiple-strand wire and found that he could light a bulb using only one strand. What was more, when he used all the strands, the light was no brighter.

One girl lit her bulb and then twisted it round and round. This was a lighthouse. See figure 10.

Some children were involved only as 'assistants' and did little more than hold one end of a wire. Often they did not stay for long with any one group, and could tell other children what was happening in other parts of the room.

Benny announced loudly that his bulb would not light, and immediately received advice from half the class. First they tried to prove that his experimental technique was unsound but it soon became clear that there really was something wrong with the bulb. There were many reasons suggested:

'Someone dropped it.'
'Too much air got in.'
'The wire was too hot.'
'Because it is white inside' (a reference to the distance piece which in the 1·5 V bulb is white, while it is blue in the others).

Colin used two batteries and connected his bulb in two ways. When the wire was in position B the light was much brighter than in position A. These became known as 'dark lights' and 'bright lights'. Figure 11 illustrates this.

FIG. 10. This child rotated the bulb and battery and called them a lighthouse.

Raymond began predicting which arrangements of batteries would produce bright and dark lights. He was convinced that his predictions would be right only when the same wires, batteries, and bulb were used.

This extract from the teacher's notes sheds some light on the learning situation:

> 'Several of the advances that different children have made and others have copied, have made me want to provide things for the next step. But during group and individual discussions it becomes obvious that they do not yet understand some of the ideas which seemed to me to be very simple.
>
> *1* Martin used a cylindrical battery upside

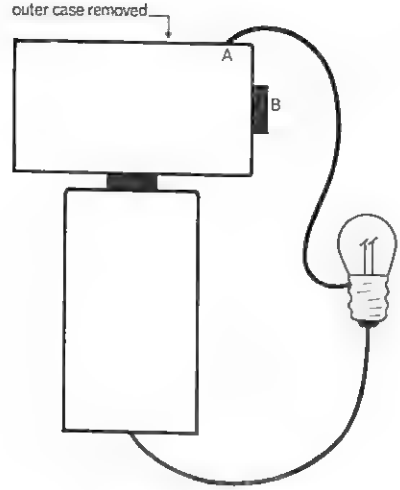


FIG. 11. A dark light.

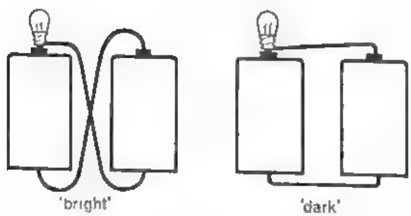


FIG. 12. More arrangements producing different degrees of brightness.

> down and *all* were staggered that it worked in exactly the same way. Afterwards, they tried the battery sideways, one reversed, and one upright, etc.
>
> *2* Many children believe that all the different bulbs give the same brightness.
>
> *3* They are sure that the wire they happen to have used is probably the only one that will produce this result.'

The teacher decided not to try to direct the children 'into the next step', but merely to extend the supply of basic materials and to encourage further general exploration.

Jane had announced, 'I am not interested in lights and I don't want a turn.' But next day, Steven asked her to hold the end of a wire and she became so engrossed that she missed her mid-morning break.

At this time, a major preoccupation was the production of 'bright' and 'dark' lights. The children were quite happy to rearrange wires to produce them and no one wondered why. You can see two experiments in figure 12.

An important aspect of this work was the cooperation it demanded. With one child operating one battery and a second child the other, some degree of mutual understanding was essential.

The study had now reached the end of its first week and some of the children were trying to associate size (i.e. physical dimensions) of bulb, wire, and battery, with brightness.

Steven and Martin said that the largest bulbs gave most light 'because there is a bigger area', but the following week they found this was not so.

It was at this point that two important observations were made. One child referred to the numbers printed on the batteries, and another pointed out that the heaviest batteries gave the brightest lights. Roger immediately retorted that the batteries with the largest numbers on them gave the brightest light, and made his point by producing a very bright light with a very small 4·5 V battery.

There follows an extract from the teacher's notes after one week:

> 'Brian and Trevor have never been near the table all week, nor have they appeared to do more than look. Both are slow and lack initiative. However, this afternoon, both sat at a table laughing as they joined their batteries and produced a light on each. Each boy lifted an end of wire on his battery to extinguish the other's bulb.
>
> 'Eleven children have worked steadily and regularly and produced most of the leading discoveries. One group of three have not involved themselves.'

A further extract from the teacher's diary records a new event:

> 'Roger thrilled me today by asking for a "thin book for electricity", and he clutched

his experiment on the writing table while he persevered with writing about it. He is not particularly able, and most things he finds difficult to describe, but he did it with a minimum of help. Throughout he was grumbled at by other children for having a battery when he wasn't using it.'

During the second week of the study, a few children became number-conscious. Apart from the 1·5 V, 3 V, etc., marked on batteries, similar numbers were noticed on the bulbs. To facilitate reading, the teacher copied them onto a piece of sticky tape fixed on the bulb. The tattered cardboard casing of the 4·5 V battery now revealed three smaller batteries 'like the 1½ volt battery' as Raymond pointed out.

When the problem arose of which bulb gave the brightest light, Martin said, 'The wire inside the bulb *must* be measured to make the same volts as inside the battery.' The children then attempted to compare voltage of the battery with brightness of bulbs of different voltages. Raymond wanted to know if his 6 V bulb would 'pop', since the sum total of batteries end to end was 9 V.

During this second week many of the children repeated things they had done during the first week. Richard and Trevor noticed that on occasions there were sparks when they disconnected wires.

The teacher wrote in her diary:

'June has not spent much time with the batteries. She watches, snatches a quick turn, and moves away. She was fascinated by a metal strip this morning, and after using it to connect batteries and bulbs, said, "It goes two ways through the metal" (length and thickness). No one else had found this!'

After half term, the children returned to school with renewed enthusiasm. They wanted to talk about what 'electricity' they had done during the holiday.

These children now encountered new obstacles. One in particular occurred when a battery was reversed in a circuit. Whereas before, a dull light was obtained, on reversal the lamp did not light at all. A major factor was that by the fourth week of the study most of the 1·5 V bulbs were 'blown' and 3·5 V bulbs were being used!

The reversal of batteries in a circuit was disturbing for several reasons. With the connection of cylindrical single-cell batteries, 'top to bottom' bright lights were obtained, and Roger found that two 1·5 V batteries joined in this way, 'give the same light as a 3 volt bulb.' But with batteries of other shapes, top and bottom were not so obvious. See figure 13.

Richard and Raymond, who were concerned with an experiment to find out if size of battery affected its life, suggested a solution for which was 'top' and which 'bottom'. Richard said: 'Just put a cylindrical battery on top and see if it makes a dull or bright light.' Martin thought that the cross (+) and dash (—) were some form of guide.

Next morning, Richard and Raymond spent half an hour with the 6 V battery and a 3 V cycle battery before making their pronouncement. Steven and Stephen independently arrived at the same conclusion, and it was interesting that both groups used the *dull* light to make their decision. About ten boys and girls now associate + and — with the 'positive' and 'negative' terminals, and thus 'top' and 'bottom' are no longer relevant to them.

Raymond had found three batteries, each marked 3 V but of different shapes and sizes, and he suspected that they would last for different lengths of time. He wired each of

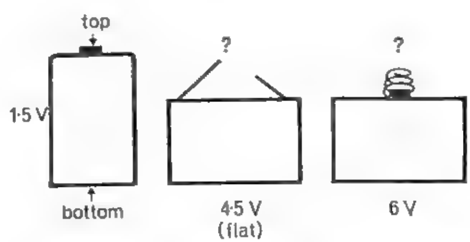


FIG. 13. Which are the tops and bottoms of the right-hand batteries?

the batteries to a bulb in a bulb holder. The holder was important as no three children could be expected to sit holding wires on bulbs throughout the life of a battery. Martin let it be known that the three batteries must all be new.

The teacher's diary says:

> 'We left them alight while going to the hall, and there was a great thrill when we returned to find the "thinnest" battery beginning to fade. It lasted fifty minutes.'

'February 25th

> Raymond set up the batteries again. The cylindrical one gave the dimmest light, but burned for another four and a half hours. A number of children soon added this to yesterday's time and found that it burned for six hours and twenty-five minutes. Only Martin wanted to know how much longer one had burnt than the other. He was very near in his calculation, but we couldn't understand his method of working. Even the head teacher found it difficult to help him. The largest battery lasted twenty-five hours and thirty minutes, by which time, some children realized that size was related to the life of a battery.'

The third week saw three major lines of interest being followed simultaneously.

The first was a continuation of previous work, that is, joining numerous batteries to bulbs to give different light intensities.

> 'Four boys working with four batteries joined together and producing four lights, were fascinated when they found that they could get two dull and two bright lights alternately by switching two wires.'

Once more, teamwork was important. No single child dominated this type of group.

The second major interest was in conductors. Zips of jumpers and shoes, the radiator, milk crates, taps, weights placed end to end and on top of each other, the xylophone, etc., were all used in experimenting.

When the conductor was small and had two definite 'ends', very little trouble was experienced, but when the object was large and immovable quite a number of children were unable to get the light to operate. The usual cause of failure was not connecting *two* wires to the object. A coloured anodized water jug was found to conduct electricity only when contacts were made at points where the surface was scratched.

The third interest was in producing lights well away from the batteries. One group joined nineteen lengths of wire together, only to discover that they had no light. They all agreed that the battery was good and thought that a new bulb was required. One was tried, but without success. Donald solved the problem when he spotted the two lead wires touching each other. 'The electricity is not getting past the join,' he said.

Trevor now announced that he was going to see what electricity would pass through, and other children pooled their resources, checked each other's findings, and displayed their results. After a time they were able to predict with considerable accuracy and began to classify the substances as metals and non-metals, with the exception of the 'lead' of a pencil. There was also an attempt by five boys to see how many objects placed end to end would conduct electricity, but this failed because of the physical problems of manipulation.

One of the objects which conducted electricity was steel wool. This was sub-divided and each fraction tested to see whether it still conducted. Eventually, Martin found that it 'sparkled' and then the light went out. He put this simple discovery to use about three weeks later when he tried to rejuvenate 'dead' bulbs. By this time, he knew how a bulb was constructed, and his method was simply to break the glass of the bulb, join the two stiff wires with a thread of steel wool, and connect this up to a battery. Once more the wool element glowed and melted. Martin was quite satisfied, saying, 'The glass is to stop the wire from melting.'

Benny had an interesting problem. How to light two bulbs on one 1·5 V cylindrical battery, having only one piece of wire! He

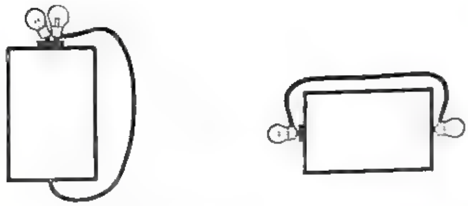


FIG. 14. Benny's experiments in lighting two 1·5 V bulbs on one 1·5 V cylindrical battery with one wire.

experimented as described in figure 14, but he arrived at the final result only after using a variety of bulbs. He found that in this position only one (1·5 V) would light if the other was a larger bulb.

The fourth week of the study saw a temporary decline in interest, and the only new one to emerge centred around the batteries themselves. When the cardboard casing came away from the cylindrical battery, a small group of children began to realize the significance of the 1·5 V cell. Each cell produced a dull light when tested and Martin observed that they 'must each be $1\frac{1}{2}$ volts because it says 3 volts on the packet.' A setback occurred when the cycle-lamp battery (3 V) was found to have 3 volts printed on *each* of the cylinders.

The teacher recorded:

'Martin and Stephen then wanted to take the $4\frac{1}{2}$ volt battery apart. I suggested that they merely try to undo the cardboard and not break the connecting wires. This they did, and Martin was immediately enthralled because the last battery was upside down. He quickly examined the packet again and found that this was the terminal marked with a dash, which he had called the bottom. He was very excited.'

The fifth week was almost entirely a 'conductor' week. The work was started by Donald who discovered that a piece of coke would conduct electricity. 'It sparks as well.' Other non-metallic substances were examined more closely.

Lynne, who had shown no interest whatsoever in bulbs suddenly produced a painting

FIG. 15. Dianne painted a bulb in a circuit.

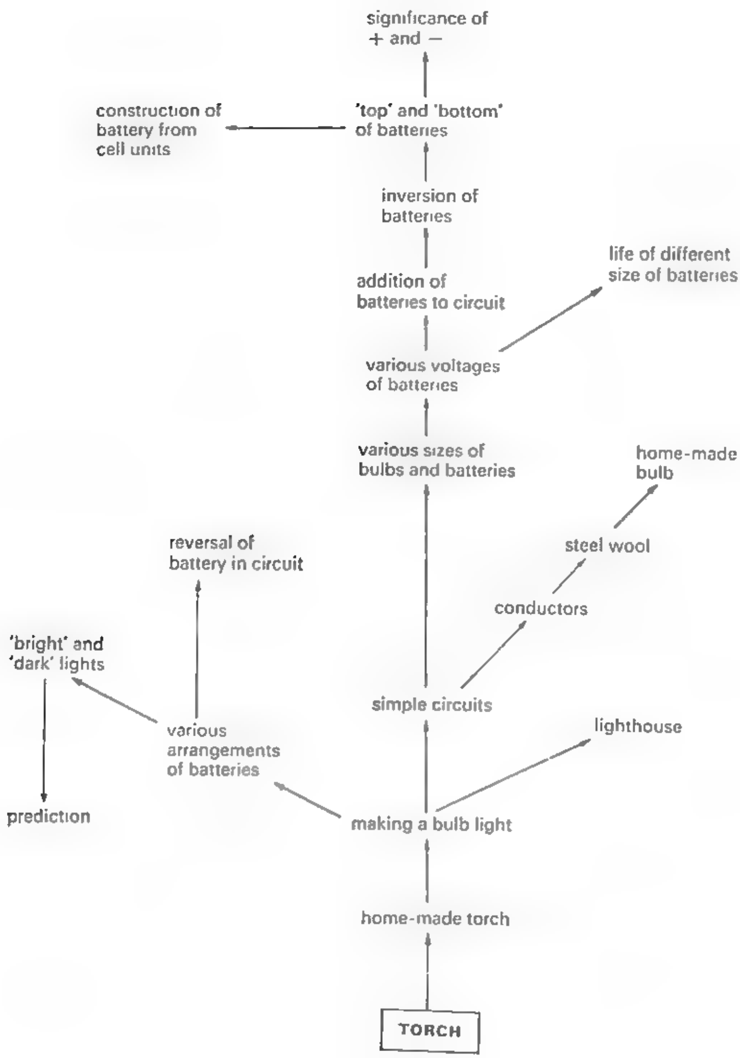
of one. Dianne followed suit, but put the bulb in a circuit. Her painting is in figure 15.

In this study, three features had occurred repeatedly, features that the teacher was sure were of prime importance.

First, the manipulative skill required in the handling of some of the materials. The thin wire, the tiny bulbs and batteries, could produce light provided that the necessary skills were sufficiently developed. To what degree the children's enthusiasm was responsible for the improvement of these skills one cannot say, but without it little would have been finished.

Secondly, patience and concentration were at a premium. The child who walks eighty yards to the headmistress's study to report his findings, only to find that his circuit for some reason refuses to produce light in her presence, and then goes away to repeat the experiment and report again, is exhibiting a degree of patience seldom found at this age.

Thirdly, teamwork, and a spirit of cooperation had also been vital.


significance of + and −
construction of battery from cell units
'top' and 'bottom' of batteries
inversion of batteries
life of different size of batteries
addition of batteries to circuit
various voltages of batteries
various sizes of bulbs and batteries
home-made bulb
steel wool
reversal of battery in circuit
conductors
'bright' and 'dark' lights
simple circuits
lighthouse
various arrangements of batteries
prediction
making a bulb light
home-made torch
TORCH

8 The lawn

Class	**6-7 years. Full range of ability**
Class number School roll	35 boys and girls 285
Term	Summer
Building	An old country house set by a spinney, with modern buildings spreading from the original structure.
Classroom	A large, well equipped, airy room with windows on two sides. Free-standing vertical display panels are arranged to form areas of interest.
School environment	Large playing area with the spinney fringing two sides of the old house. Set within the heart of a large post-war council housing estate.
Local setting	Midlands. About three miles from the centre of a wealthy city with light industries.

The entire class of thirty-five was sitting on the grass outside the classroom when the teacher asked them to look around. 'Are we sitting only on grass?' was her opening question, and it was one which led the children along a wide variety of trails over the next five weeks. The class during this period followed the usual routine of any lively infant class. While some were concerned with the lawn or questions connected with it, the rest ignored them and followed many other interests.

The teacher's question was immediately taken up by the group. 'We are sitting on weeds as well as grass,' said a number of children. Richard noticed that some weeds occurred singly, others in clumps. According to the twins and Terry, there were more clumps around the edges of the lawn and by the school gates, with only a few on the lawn itself. The weed was a plantain and the twins and David and others tried to reason why this particular balance should exist.

'The plantain is where we tread most often.'
'Treading kills the grass.'
'Seeds fall on the bare earth.'
'Plantain grows best on bare ground.'
'The plantain smothers any young grass.'

Whether or not this is a true account is not of prime importance. What matters most is the search for a reasonable answer.

The teacher encouraged the children's natural desire to collect weeds and this resulted in a class herbarium. Within ten days, by referring to pictures and matching their specimens against them, the children had

correctly identified and named at least eight common weeds. Neil could neither read nor write, but he could identify and count the occurrence of birdsfoot trefoil and after a month was able to recognize the word.

A chance observation by one child that someone was standing on weeds during a counting session started a competition between children to see who could cover the most weeds. This was the point at which the teacher suggested they should find the total number of weeds on the small lawn—about forty square yards. It was interesting that first one child and then another suddenly realized that it would be necessary to organize the way they counted in order to arrive at any result. Until this point was reached there was bedlam, and when someone saw that some demarcation of the lawn was required there was also bedlam. There were cries of 'I know what to do'—and then would follow suggested solutions. The teacher decided to hold a discussion, and it was unanimously agreed that the lawn would have to be divided into shapes so that none of it would be omitted and yet everyone would cover a similar shape and size. After considering the equilateral triangle, the rectangle, the circle, and the hexagon, the class decided that the rectangle would be the easiest shape to repeat. Paper, cloth, cardboard, and wood were all suggested for the dividing lines. Then David suggested string and Elizabeth a one-yard square.

With the teacher's help, the children divided the lawn into square yards. They can be seen at work in figure 16. One group of three children, and four others, raised the problem of how long weed seeds took to germinate. 'Some seeds will be weeds if we count them next week,' said one of them. This raised another problem: how to remember one's own square so that the recount would be of the correct set. Many solutions were suggested, the most acceptable being Timothy's. 'Write your own name onto a piece of paper and peg it into your own square.'

Eventually the teacher showed them how they could form a matrix with numbers across and letters up and down. The children suggested calling each row a colour. This was rejected during discussion because coloured paper had been stuck onto each of the potted weeds in the herbarium to help with the reference. Some children wrote down the names of the weeds, while others wrote down the allotted colour. Some children (Timothy, Christopher, and David) were able to count the number of each type, whilst Neil, Tony, and others matched one weed to one square on the squared paper. Nevertheless, all the children knew which weed occurred most, least, etc., by comparing the heights of the column graphs.

David B. wrote:

> 'Paul and I made a graph about all the weeds in forty square yards and there were 703 clover, 572 plantain, and 334 yarrow, 234 daisies, 74 buttercups, 35 hawkweed, 20 dandelions, 18 ragwort, 3 shepherd's purse, and clover was the most and shepherd's purse was the least.'

Of the thirty-five participants in the activity, fourteen asked permission to make their own square where they wished. After much discussion it was decided that pegs, a yardstick, and some string were required. Fresh varieties of weeds were found and these were sorted and matched with pictures in books. Often these pictures were not of good quality and the children experienced great difficulty. Expressing their findings meant that the children became involved in further graphical expression, and there was much child-to-child consultation.

An extract from the class teacher's report reads:

> 'Four boys asked if they could have a square in the spinney and cut down the plants to see what would happen. We decided that we must graph everything in the square prior to the cutting. Making the square in the high grass proved difficult. Identification here is also proving most difficult, and we are waiting for some to grow bigger. The finding of lots of tree seedlings caused great excitement!

FIG. 16. The children investigating their squares.

'. . . One group said that it would be easier to take a patch of grass and let it grow. Over half the class wanted to do this, and I had to confine it to fifteen.'

Note how there was another upsurge of interest among most of the children because '. . . four boys asked if they could have a square in the spinney.'

Actually, the four boys in the spinney never reached a solution to their problem because they enthused over a more important topic, which was taken up most readily by the rest of the class.

Those children who had decided to cut the grass and leave it to grow became excited when flowers appeared. They became fascinated by the hop trefoil, the birdsfoot trefoil, and the thick, bushy clover. Careful observation went on over five weeks, by which time those not initially concerned with the problem had made it their concern. As before, counting or matching led to pictorial representation.

The four boys in the spinney deliberately laid out their square so as to contain an old branch and a few nails. On the branch they found some earwigs which, they informed the class, must have come from the tree from which the branch fell.

The entire class moved into the spinney armed with sheets and sticks; to catch the earwigs as they fell and the sticks with which to beat the branches. After ten minutes the class reassembled and discussed its findings: black, green, yellow, red, and brown flies, caterpillars, earwigs, moths, and spiders.

Next day the children complained that they had to beat a number of trees before any living creature was discovered. Where had they gone to and why had they gone? Some children said that they could not have beaten as hard as they did yesterday. Some said that the insects that were knocked off yesterday had not had time to crawl back, and yet a third proposition by a child was simply, 'The wind did it.' One child said that the creatures were in the grass, another said that they were under the bark of the trees, yet another said that they were hiding under stones, and yet another suggested that they were round the other side of the tree! No attempts were

made by these children to prove their statements.

The teacher reports:

'We had several books, not one of which was much help. This work on insects has made me much more observant, but also much more bewildered about even which group some of the insects belonged to. Beetles and flies and even tiny hoppers appear almost identical even under a magnifying glass. I therefore decided not to worry unduly about perfect classification.'

This was a wise teacher!

Here are some extracts from the children's writing:

TINA: I found twenty-three hoppers and a mother hopper on the weeping elm.

REJEENA: I saw some insects climbing on leaves and an earwig and a black thing with six legs.

DAVID: I saw the ants talk with their feelers and I saw the ants milk the greenflies on the crab apple tree.

TERRY: I found a lesser housefly in the cloakroom and its body is furry and its legs are furry and it was dead and it is hard to find in a book.

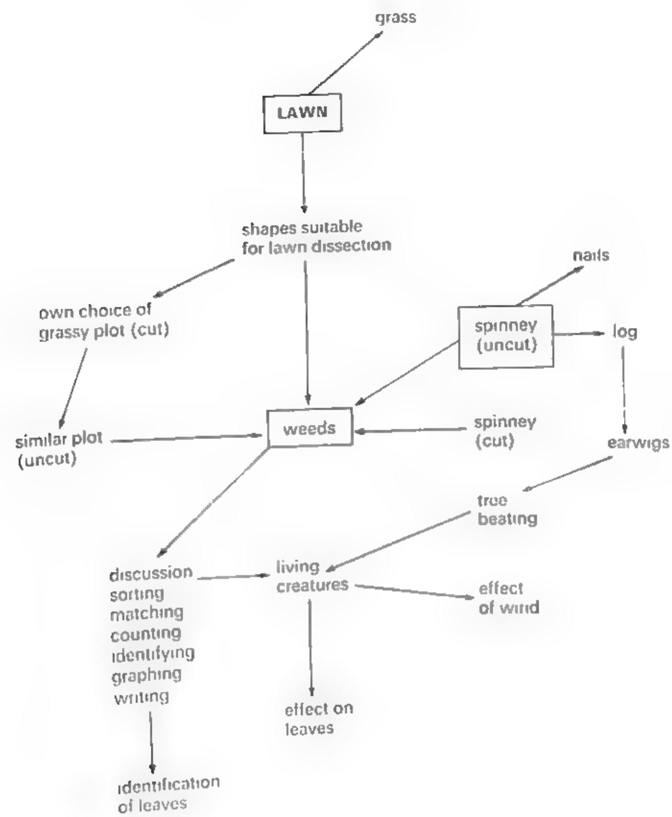
BELINDA: On my way to school I saw some insects going up a tree.

Two girls noticed that where insects were found on leaves the leaves were curled up or had holes in them. This raised a further wave of excitement. Which leaves were most affected? This question was put by the teacher. Which insects ate the leaves? This was a child's question. An attempt was made to find answers, but either the insects were too small and escaped from their container or the leaves dried up (none of the children thought this was particularly significant).

Throughout the whole of this work, certain important points were noted. The weeds, the living creatures, and to a lesser extent the leaves, were sorted, matched, counted, recorded in some form, and written about to a degree varying from child to child. No child worked with all of them. No child failed to join some of the work, even though there was no direction by the teacher. If the weeds failed to promote a spark of interest then the lawn dissection did—or the gaily coloured flies, or the 'black thing with six legs', and so on. Certainly, the instant at which interest waxed or waned was obvious. The child would disappear indoors, or appear at the teacher's elbow with something to state or to ask, or possibly in order to try out a newly acquired word. When he was interested he usually wanted to talk.

The children were constantly applying previously acquired notions of number with very little effort, as when Tina noted twenty-three hoppers, Rejeena saw the six-legged 'black thing', and Belinda began a story like this: 'Mother and Father greenflies have three babies every day, in two days six babies . . . in ten days thirty babies.'

The relative values of numbers were being displayed repeatedly while the children compiled graphs—a convenient method of presenting information afresh and storing it in a compact form. All the children who produced graphs interpreted them, on returning indoors, in a way which showed that they were understood. 'This is the story of the square El,' wrote Christopher. 'Insects don't like wind,' is Terry's caption.


grass
LAWN
shapes suitable
for lawn dissection
nails
own choice of
grassy plot (cut)
spinney
(uncut)
log
similar plot
(uncut)
weeds
spinney
(cut)
earwigs
tree
beating
discussion
sorting
matching
counting
identifying
graphing
writing
living
creatures
effect
of wind
effect on
leaves
identification
of leaves

9 Sound I

Class	**6-7 years. Full range of ability**
Class number School roll	35 boys and girls 285
Term	Summer
Building	An old country house set by a spinney, with modern buildings spreading from the original structure.
Classroom	A large, well equipped, airy room with windows on two sides. Free-standing vertical display panels are arranged to form areas of interest.
School environment	Large playing area with the spinney fringing two sides of the old house Set within the heart of a large post-war council housing estate.
Local setting	Midlands About three miles from the centre of a wealthy city with light industries.

A large group of children were making music in a corner. They were striking medicine bottles, a milk bottle, chime bars, a dulcimer, a drum, and some triangles.

They already knew that striking any object would produce a noise, and that in order to produce a different noise they had to hit a larger chime bar, or a bigger bottle, or partly fill a bottle with water. Something had to be changed in order to produce a different sound.

The teacher then split the group by asking: 'What makes the Sooty xylophone produce different sounds, when all the metal bars are the same length?'

One section of the group drifted away, not really being interested. The rest suggested some answers, but these were rejected by certain children. An example was: 'Each bar has a different letter on it and this makes the sound alter.' Paul showed the rest of the children that this could not be so because two of the bars had a C stamped on them and they made different sounds. Another was: 'Some of the bars are thick and some thin.' Timothy rejected this because 'F and B are the thickest and A and C are the thinnest!' An intelligent answer, yet one he could not amplify. Another idea—'The colour of the bar changes the sound'—seemed so unlikely that no one suggested that the bars could be painted the same colour in order to verify this statement.

Only four children actively sought a solution to this xylophone problem.

Richard and Paul measured each bar in turn and found that they were identical in

length and breadth (Richard checked the diagonals). One of them noticed small notches on the underside of each bar. Richard attempted to 'measure' these notches with a ruler, while Paul attempted to weigh the bars. Ounces were too heavy, so he tried wooden cubes. Wooden cubes were too heavy, and he could not use peas because 'they are not all the same', so he eventually balanced one bar against the other and discovered that no two were the same weight.

Michael thought that you *could* have different sounds associated with similar shapes and so he made a papier-mâché reproduction of the class wooden pyramid, and another one from clay, tested them, and reported, on the clay one, 'This made no sound.'

Timothy assumed that the weights of the xylophone bars were equal, although it was he who had spotted the different bar thicknesses. Possibly at this stage he took weight to be a function of two dimensions only. He then demonstrated, or so he imagined, that equal weights can be made to emit different sounds by striking two identical medicine bottles, one filled with water and the other with sand. He filled other bottles with sawdust, paint, soil, and soap solution, struck them in turn, and decided that liquids give the same sound and non-liquids give another. Few children agreed with him.

Meanwhile, additional instruments had been collected in the search for one which would play a tune without something being changed. These included a violin, recorder, tin whistle, flute, and drum.

Although these children were unable to reach a solution which was satisfactory to all, they had discovered on the way that a sound was made if something vibrated. Paul first used the word 'shivered'. Some vibrations could be seen clearly, others could just be felt through the finger tips.

All the class became 'vibration' conscious. They looked inside the piano and saw the strings vibrate and they felt this through the case. As with the violin, although not the piano, these strings were all equal in length and of different thicknesses. A piece of Perspex made a sound when scraped, and it also vibrated in the hand. Geoffrey's ruler, when trapped under a desk lid, could be made to make a sound and be seen to vibrate. Rejeena said that the top of her nose vibrated when she hummed. Each bottle of the milk bottle scale made by David and Geoffrey could be felt to vibrate when struck. Paul and Richard made a one-string fiddle and found out that no matter where it was plucked, 'it always vibrates most near the middle'. They used a ruler to verify this discovery. Two boys roamed the classroom with a tuning fork, touching objects with the vibrating open end Most substances could be made to vibrate but, they reported, not soft substances. Paper was best, it made a noise like a bee. When the teacher asked these two boys, during a discussion, what made a bee buzz, they guessed it was the vibrating wings!

Paul made whooshing sounds with his long cane. 'The faster I turn, the higher the sound and the more it vibrates,' he said. This boy knew from experiences such as scraping objects, opening a squeaky door, causing rulers to vibrate differently, blowing on a comb and paper, etc., that the greater the frequency, the higher the associated sound.

The twins suddenly announced that air vibrates! 'Well, it must, because when we blew into the bottle it [the bottle] didn't vibrate. So it must be the air vibrating because there is a noise!' Later the same day they explained to the teacher why the flute was able to make different noises when different holes were stopped.

By now, Paul and Terry were following instructions on how to make a telephone, in a book where they also read about the range of frequencies of voices, instruments, etc. Paul asked the teacher to make some sounds because he wanted to do a sum! The teacher made various noises and Paul estimated the frequencies like this:

10 (squeaking door)
138 (teacher humming), and so on

His final summation was in the region of 3,500 c.p.s. Arithmetically, this was incorrect,

but this he failed to spot. But the important moment was when he suddenly realized that his answer was nonsense: the answer 3,500 was the vibration rate of one high note, and several low notes played together could not possibly be the equivalent of one high note!

An extract from the class teacher's report reads as follows:

'We found out that:

1 Length alters the sound of:
hammered nails
rubber bands
piano wires
one-string fiddle
rulers in desk

2 Thickness alters the sound of:
violin strings
rubber bands

3 Vibration causes sound shown by:
feeling the piano
clapping
watching electric bell
feeling one's throat
watching bee's wing, etc.

4 Sounds can be produced by:
rubbing
blowing
plucking
tapping, etc.'

This investigation lasted on and off for about three weeks, during which time everyone was involved to some extent. Four children were completely absorbed in the topic and became familiar with *all* the findings mentioned.

The word 'vibration' appealed to many, perhaps because they enjoyed its sound or possibly because the occasions on which vibrations could be produced were limitless. It was only necessary to feel one's throat and the need for a word to describe it was there.

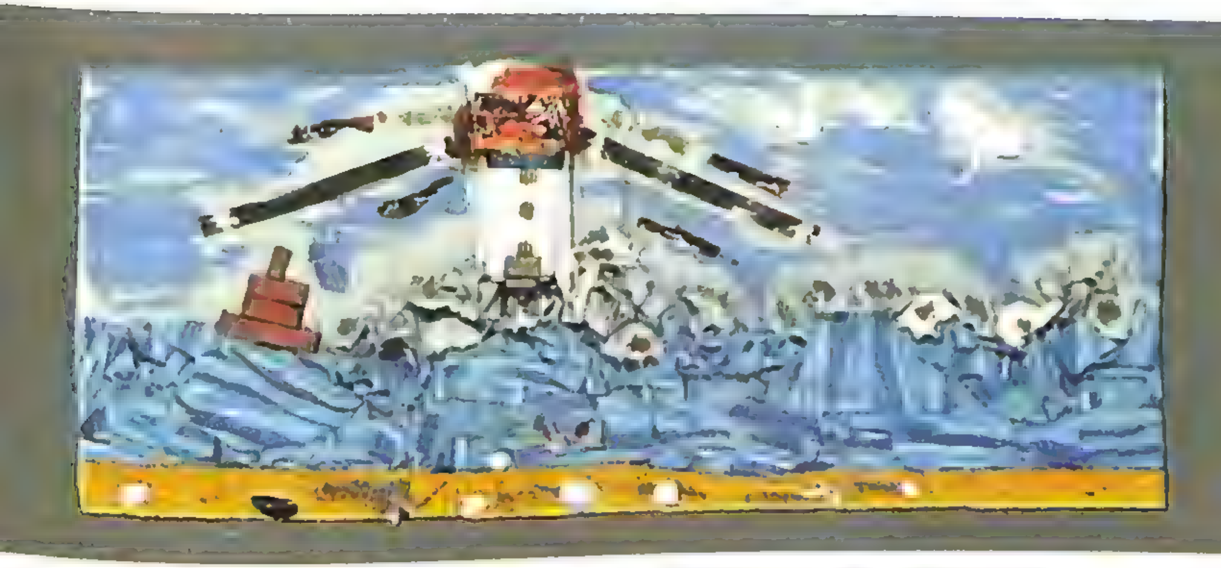
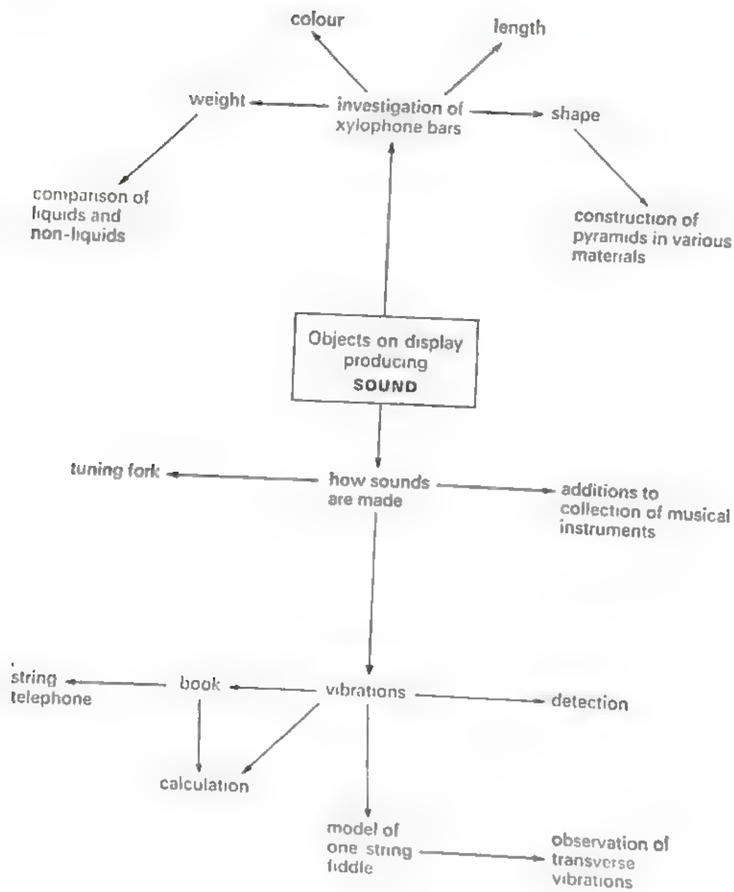


PLATE 3. The children's collage picture of the lighthouse model (p. 44)

PLATE 4. A spatter print around leaves (p. 76).

PLATE 5 Willow charcoal, ash, and red earth drawing (p. 51)


colour
length
weight
investigation of xylophone bars
shape
comparison of liquids and non-liquids
construction of pyramids in various materials
Objects on display producing SOUND
tuning fork
how sounds are made
additions to collection of musical instruments
string telephone
book
vibrations
detection
calculation
model of one string fiddle
observation of transverse vibrations

10 A sunflower

Class	6-7 years. Full range of ability
Class number School roll	22 boys and girls 156
Term	Autumn
Building	Built 1877. A two-storied brick building with stone staircases and dark corridors.
Classroom	Old fashioned, with high windows, but made pleasant and light with pastel colours. Storage space is very limited, but there is adequate room for this small class.
School environment	The school is situated directly on a busy main road.
Local setting	North-west England. In the heart of a large industrial city, surrounded by industrial concerns of all kinds and extensive post-war housing on the cleared bombed sites.

Early in the autumn term a large annual sunflower, complete with roots, was taken into the classroom.

These children had never seen anything like it before. 'It reaches nearly to the ceiling —it's like a tree,' said Thérèse, and Barbara was sure that it was 'Weed' (from *The Flowerpot Men*). They began to handle it, feeling the thick, ridged stem, lifting it to judge its weight, touching the large rough leaves ('like elephant's ears'), and marvelling at the size of the flower head. This started them measuring, not only the sunflower, but also themselves, the room, and the things in it. They compared their own heights and weights with the plant, and measured paces and distances inside and outside the classroom. A life-size painting of the sunflower was done by Jean, and Joan and measured to see if it was correct. It was the largest painting these children had ever done.

They examined parrot food and discovered the sunflower seeds—black, white, and striped. Much discussion arose about what the seeds would be like when *their* flower had died. Later, when it was dry, they recognized the spiral arrangement of the seeds on the flower head and, quite spontaneously, traced the pattern with their fingers. All the seeds were white and the children wondered if, when a striped seed grew into a plant, it would have striped seeds too. They decided that the only way to find out was to grow them.

Soil to these children is 'dirt', or, if wet, 'muck'. Some good garden soil was brought in and they began to examine it, finding bits

of dead leaves and roots and tiny stones, and discovering that it felt gritty. Stephen looked at some with a magnifying glass and said he thought he could see sand. They set to work to mix their own soil from leaf mould, old turf, and sand, finding the best 'riddles' for the job from a selection provided. One of the highlights of this work was when they discovered that they could make sand by rubbing pieces of sandstone together. This became an absorbing interest that lasted, on and off, for nearly a fortnight and two differently coloured sands were produced—one red, the other yellow. The children were most careful to keep them separate and decided that they would make a desert 'garden' with the yellow sand. Other stones (pebbles, slate, limestone, etc.) were picked up and rubbed together but they were discarded immediately because they did not make sand! Later the children came back to them and explored the different textures and degrees of hardness.

At this time the class went out onto the bombed site near to the school looking for 'hard' things, 'soft' things, and 'shiny' things. When they came to sort out their finds they had difficulty in grouping because some things were both hard *and* shiny. The children were constantly handling these things, talking about them to each other, comparing degrees of hardness, softness, and shine, gaining much experience of texture and weight, and extending their vocabulary. They were not encouraged to bring in stones because if they were seen picking them up they might be in trouble with the police.

A complete runner bean plant was brought in by the teacher and the children then wondered if it was possible for a plant to be even taller than the sunflower! The children unwound the 'twisty-twirly' stem, stretching it out to measure it—they were determined that it was going to be taller than the sunflower—and it was, at 7 ft. 8½ in. Soon a life-size painting of the bean plant was up on the wall beside the one of the sunflower, together with the block graphs of their heights, and there was great excitement when the children found that the bean plant was exactly as high as the combined heights of Barbara and Thérèse. 'If Thérèse stands on my head, we'd be as big as our painting,' said Barbara.

As the bean plant began to die the children wanted to make their own plant and they all set to work making leaves. 'There are three leaves; it's like the shamrock', said Stephen. Tony and Francis chose to draw the pods and then came the problem of how to make the stem. After a lot of discussion they decided to use string because it was soft and would twist round the supporting stick. Then they wondered, 'How can we make it green?' They tried putting it into green paint-water (left from painting the leaves) and found that it would have to soak a long time. Marion took it out next morning and put it on the radiator to dry. The leaves flopped and looked dead when put on the string. Then Stephen produced some wire that he had picked up on the bombed site. It was just the thing to stiffen the leaves and the children were delighted with the results of their efforts.

Using the soil they had mixed, the children planted a variety of seeds, collected from dried fruits their teacher had brought in earlier, some pips, and, of course, the sunflower and bean seeds—also a 'monkey nut' from the parrot food, which they expect to grow into a monkey tree!

The teacher had been amazed and delighted at the way in which interest and enthusiasm had grown: each day now the children were bringing in something they had found or discovered, and the parents were asking if they might come to see what it was they were so excited about.


SUNFLOWER PLANT
comparisons with small sunflower plant from another garden
sunflower designs for book covers
life-size painting of whole plant
discovery
weight
height
compared with heights and weights of children
great interest in measuring developed
flower head diameter
spiral pattern of seed arrange-ment
number of seeds
weight
many other seed boxes examined and seeds collected, dried and packaged for next spring
'parrot' food containing sunflower seeds
seeds as food for animals (harvest theme)
planting of seeds
making seed boxes
RUNNER BEAN PLANT
seeds counted
measurement: it *had* to be taller than the sunflower
'making' soil from leaf mould, turf and sand
sieving and mixing
sandstone
discovery of how to make sand
planting of seeds
pebbles, slate, limestone
cut-out model of bean plant made to replace the real one which was dying
growth of seedlings
degrees of hardness discovered
went outside to search for hard, soft and shiny things
vocabulary
effect of light
collections built up, children 'classifying' their finds
discovery of qualities shared: hard and shiny, soft and shiny, etc.

11 Rainbow colours

Class	**6-7 years. Full range of ability**
Class number School roll	22 boys and girls 156
Term	Spring
Building	Built in 1877. A two-storied brick building with stone staircases and dark corridors.
Classroom	Old fashioned with high windows, but made pleasant and light with pastel colours. Storage space is very limited, but there is adequate room for this small class.
School environment	The school is situated directly on a busy main road.
Local setting	North-west England. In the heart of a large industrial city, surrounded by industrial concerns of all kinds and extensive post-war housing on the cleared bombed sites.

The discovery by the children of rainbow colours on the floor of the hall and in the fish tank in the classroom led to further investigations.

The following items were put on a table: rolls of coloured Cellophane, a triangular glass prism, a rectangular block of glass, mirrors, torches, liquid soap, and wires. Some of the children unrolled the sheets of Cellophane and were thrilled by peering at each other through them and putting them up against different things. Barbara was wearing a blue cardigan, but when she held some yellow Cellophane against her it looked green.

Sandra, who looked at her hands through the Cellophane, found they were first green, then yellow, and drew round her hand and stuck the different colours over the outlines. By chance the children discovered that they could make a new colour by putting two of the transparent sheets together. Some made masks, filling each eye with a different colour, then looking at pictures and many other things and telling each other what they looked like. Pauline and Thérèse spent quite a time wearing their coloured spectacles, and trying to pick out coloured pegs from a box which was always available, and guessing the colours. Some of the children's work can be seen in figures 17 and 18.

Tony picked up the prism, holding it in his hand as if judging the weight; he did not say anything but moved round the room looking at things through the prism. Then he said to the teacher: 'You see the shop over there? Well, in the prism, it is over here.' He also

FIG. 17. Looking at a hand through coloured Cellophane.

FIG. 18. Looking at things through masks with coloured eye-pieces.

FIG. 19. Catching the sunlight in a prism.

discovered that, if he looked through the prism in a certain way, 'everything has rainbow colours round it.' Stephen was intrigued with the rectangular block and went off with it, turning it round and looking at things through it. He was surprised, when he looked through it and tried to put something on the table, that the table 'had moved'. He also said things were upside down if he looked through the edge.

The teacher had left plenty of bubble-making material on a side table and when one of the children started to use it, most of the others soon became interested and, very soon, all the class was blowing bubbles. They bent the wire into many different shapes and sizes. If the frame was too big the soap film would not hold, but, whatever the shape, the bubbles were always spheres. The children saw the reflections of the window in the bubbles and were thrilled to see the rainbow colours. Sometimes two bubbles stuck together and they noticed 'it is flat where they join.' Barbara found that she could catch a bubble with the wire frame, 'but only if it [i.e. the wire] is wet'. The interest in rainbows and colour captured the whole class—they asked if they could learn the song, 'Somewhere, over the rainbow', made their own 'rainbow table', and each day added something else to it.

Tony found a glass slide and an oval mirror amongst the class's 'shiny' collection, so he transferred them to the rainbow table. Joan's father made her a periscope and the children discovered how the mirrors were placed and experimented with other mirrors, finding that they could see their own ears and the backs of their heads. The teacher now added a spoon, a collection of rainbow marbles, and some coloured plastic bowls. Caroline sidled over to the rainbow table, picked up a coloured bowl, and quietly walked round looking through it. Some of the children painted rainbows (they discarded crayons as unsatisfactory), arranging the colours in the right order after some argument about which colour should come first. In the end, they went over and looked through the prism and decided on purple. They added the Ark to their

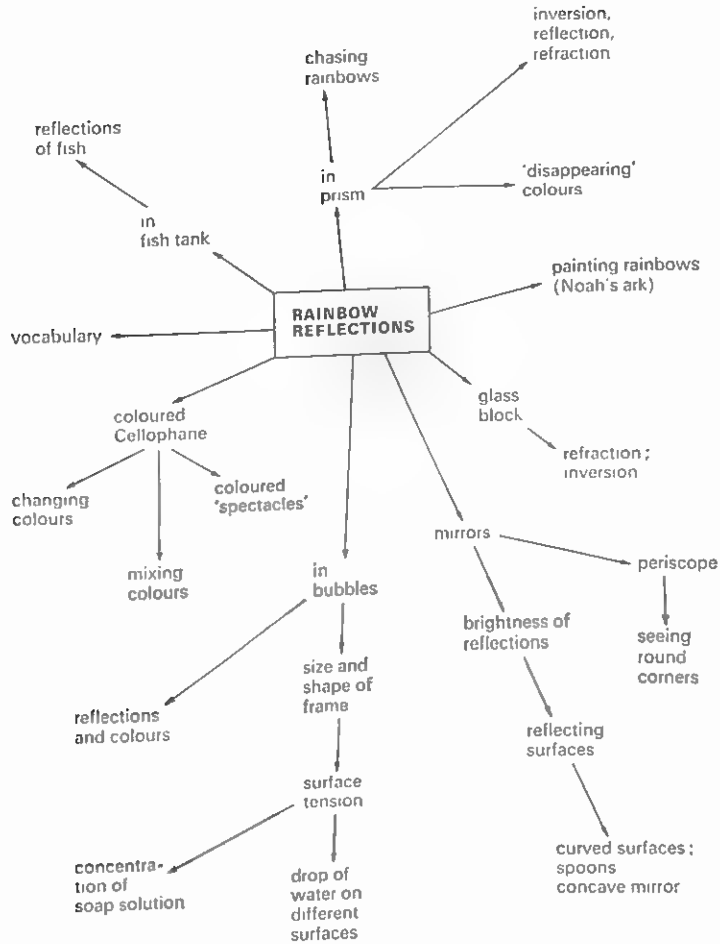
pictures and were delighted with the results.

One bright sunny morning, when the class was in the hall, they discovered the shape of the windows on the floor and their own shadows in them. They realized that a shadow is caused by blocking out the sun. They went outside, saw the sun blocked out by the wall, and said the windows let the sun through because they were made of glass, and the wall stopped the sun because it could not go through bricks. It could not go through their bodies either. After this, as figure 19 shows, they played with mirrors and glass and prisms and sent the light bobbing all over the room, now realizing that they could look through glass but not through a mirror. New words were learned and understood: transparent, opaque, reflection, reverse, opposite, cloudy, and smeary.

Back in the classroom some of the children went to see if the rainbow in the fish tank was still there. 'We only have two fish, yet when I look from here I can see six,' said Joan. Some could see even more. Then they exclaimed, 'The rainbow is still here.' John was making a rainbow with the prism and as he moved it, it travelled over some pieces of differently coloured Cellophane lying on the desk. The children noticed how some of the colours 'disappeared'. They chased the moving rainbow and saw that it was brightest when it rested on Thérèse's white cardigan and on the ceiling.

Stephen found a picture in a book showing a drop of water acting as a magnifying lens. Could he try to use one? He put a drop of water on some newspaper. 'It has gone away,' he said. Next, he tried the surface of the glass block. 'It has spread out.' Then he tried some waxed paper. 'It's like a bead now.' He crayoned the newspaper to make it waxy and convinced himself that the drop of water made the print look bigger. Later he was seen with an empty milk carton, moving it about to get the drops of milk to coalesce.

This work was done during the last two or three weeks of the spring term, after a student had been taking the class, and it came to an end with the term. It would be interesting to see how the children would react to these materials if they were presented at a later date.


RAINBOW REFLECTIONS
in prism
chasing rainbows
inversion, reflection, refraction
'disappearing' colours
in fish tank
reflections of fish
painting rainbows (Noah's ark)
vocabulary
coloured Cellophane
changing colours
mixing colours
coloured 'spectacles'
glass block
refraction; inversion
mirrors
periscope
seeing round corners
brightness of reflections
reflecting surfaces
curved surfaces; spoons concave mirror
in bubbles
reflections and colours
size and shape of frame
surface tension
concentration of soap solution
drop of water on different surfaces

12 Parkland

Class	**7-11 years. Full range of ability**
Class number School roll	26 boys and girls 41
Terms	Spring and summer
Building	Nineteenth-century church school.
Classroom	Dark, very high windows, sloping window ledges, shortage of display space. Same room used for school meals.
School environment	Village school. Asphalt playground surrounded by fields and woodlands.
Local setting	East Midlands. Very remote village. Fairly isolated community.

The amount of purposeful talking is a striking feature of this classroom. Individual problems are discussed with the teacher; sometimes a particular problem is put to the whole class or to a small group. Before work is displayed, the children concerned discuss amongst themselves how it shall be done, and then they consult their teacher and iron out the difficulties with him.

Naturally, then, when we asked the school to become involved in the Nuffield Project, the headmaster discussed the idea with the children, and it was they who suggested the park as a subject for study.

Having discussed the problem, they wrote letters asking permission to use a private path giving access to the park, and to the Forestry Commission, whose cooperation, it was felt, would be needed before the work had gone very far.

The first visit to the park was by the whole class and was used to decide what should be studied. They quickly concluded that there was far more material than they could deal with, and that it would be better to restrict their attention to trees. The first task was to count and identify the trees, as far as they were able. In fact, they had doubts about the identities of only two trees, and their suspicion that these were Norway maple and Turkey oak proved to be correct. This visit also led to the decision to keep field diaries and to draw block graphs showing the numbers of trees.

Back in the classroom, the children argued out how to make a start on the problem, and they determined to work in small groups, each group including children of various ages. This decision was based on the belief that the older children would be able to help the

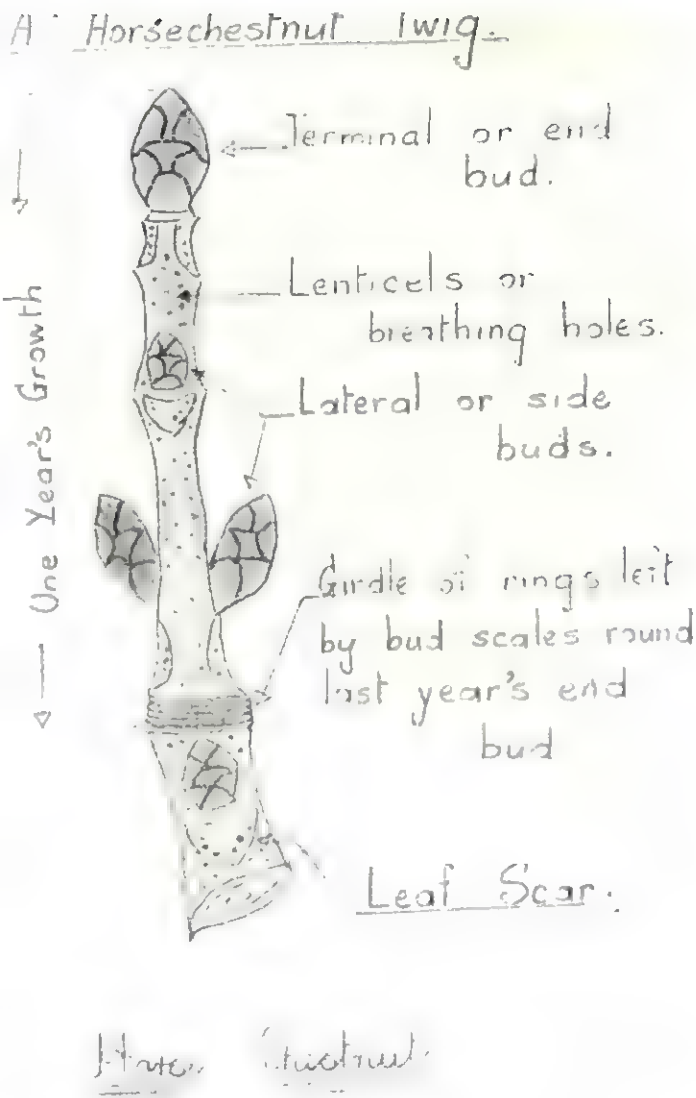
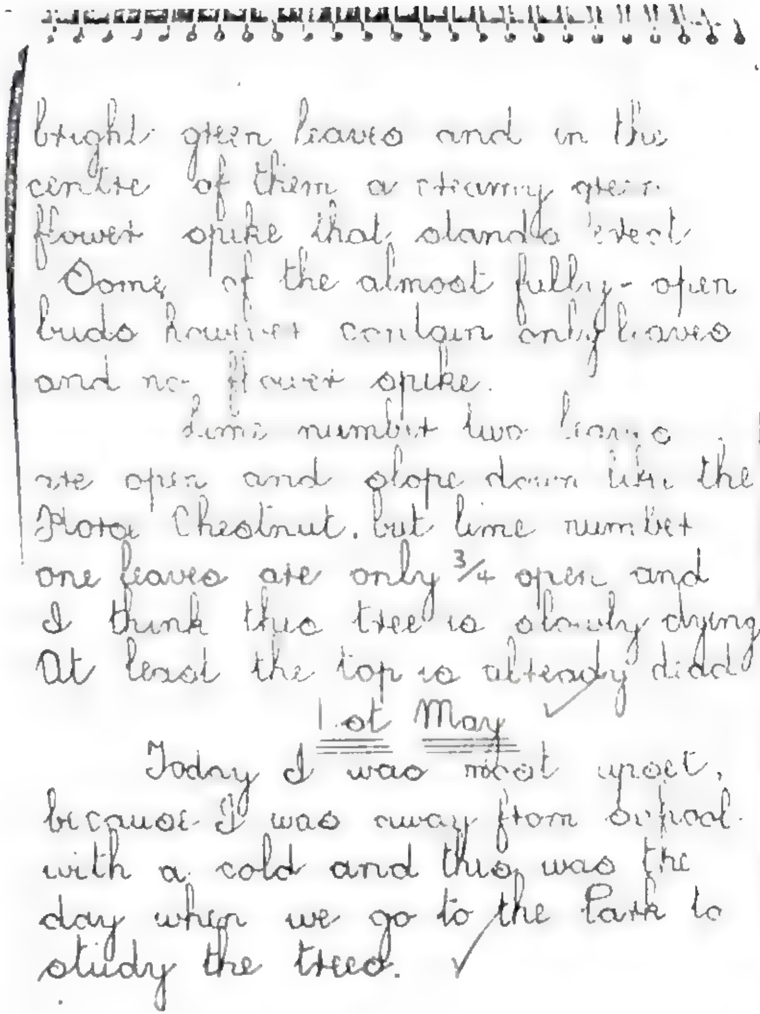


FIG. 20. The child collected a specimen, looked it up, and painted it.



bright green leaves and in the centre of them a creamy green flower spike that stands erect. Some of the almost fully-open buds however contain only leaves and no flower spike.
Lime number two leaves are open and slope down like the Horse Chestnut, but lime number one leaves are only 3/4 open and I think this tree is slowly dying. At least the top is already dead.

1st May

Today I was most upset, because I was away from school with a cold and this was the day when we go to the Park to study the trees.

FIG. 21. Tessa's diary.

younger ones, whereas a group made up entirely of young children would be faced with too many obstacles.

The children then decided on their own groupings, the teacher selecting the group leaders. From then on each group concentrated on a particular kind of tree, although there was a great deal of class discussion as well as movement between groups by children who wanted to know what was happening elsewhere.

Some of the children started to collect twigs, but when they felt that the twigs themselves were not a satisfactory form of recording, they decided to make plaster casts. This was not without its problems, with early mixes being too wet and later ones setting too quickly, and one boy was deputed to find out what proportions of plaster and water gave the most satisfactory consistency.

In order that the casts could be painted, the twigs were examined with care, and a great deal was learnt about details of appearance. Several children gained new insight into the mixing of paints to achieve particular qualities of colour.

Other records took the form of drawings and paintings. The children used reference books extensively to discover the names of detailed structures.

This work was not only proved satisfying for them, but also led to greater confidence and ease of recognition. Here the teacher gave a strong lead by pointing to the possibility of recognizing trees by their leaves, buds, and other characteristics. One of the paintings is shown in figure 20.

Work continued during the Easter holiday when a large proportion of the class visited the park. Attention was now focused on seeds found under the trees, and back at school a selection of seeds was planted in pots and boxes and allowed to germinate. This was to determine what kinds of seeds they were and what proportion of them was capable of germination.

At the beginning of the summer term, several children were surprised to see that some of the trees were flowering, even though they had no leaves. They were now keeping field diaries, and began to compile progress reports on foliage to enter in these. The facts were assembled formally at a certain time each week, but the entries were written freely by the children. One of them can be seen in figure 21.

It was at this point that two boys who were studying ash trees in widely different positions in the park realized that one tree had flowered two weeks before the other. Tommy thought that it was related somehow to temperature and that it would be useful to know something about ground and air temperatures. These were measured.

By now, the leaves were opening and there was a general interest in the changes occurring during growth. Leaf shape and details of veins and margins were examined. The class as a whole decided to keep a record of the leaves, but one group in particular was dissatisfied with the method of pressing or of sticking leaves on cards, since the results were fragile and short-lived.

This group investigated the relative values of different materials and methods of recording. They were given a free hand and a wide range of materials in their efforts to find the best way of taking permanent leaf impressions. These included rubbings, pressings, and spatter prints, one of which is shown in plate 4. The exercise became so absorbing that the children worked at home in the evenings and compared notes at school each day.

Tessa, who had become engrossed in spatter printing, wrote:

> 'I first tried using white paper, stuck the leaves down and then tried using a nylon tooth-brush. It came out fairly well, but then I used a natural bristle brush. I used a pin to flick paint from the hairs of the brush onto the paper, but it kept slipping out of my hand. Then I held a nail to flick the brush, and it came out better. I tried it with powder paint, which came out blodgy, and then poster paint which gave the right effect. I tried using white paper,

but this didn't give such a good effect as the green card.'

At about this time, there was a period of strong winds, and during one of their visits to the park the children found a branch lying on the ground under the tree. Interest was high. Why had it broken off? Examination showed that it was not rotten. Could it be the wind? They were not very convinced of this. The most popular idea was that the weight of leaves had caused it to fall.

What was the weight of leaves? Indeed, what was the weight of leaves on the whole tree? The children decided to count the leaves on one section of the branch, and weigh them. Then, by estimating how many similar sections there were, they could calculate the total weight.

The leaves from the broken branch were tied into a bundle for weighing, and it was a matter of interest that when they were weighed again, they had lost weight. By now, several new lines of investigation had been opened up. The children had determined the weights of equal numbers of leaves from different kinds of trees, and drawn graphs of their findings.

There were also graphs showing the relationship between leaf size and weight, and between size and kind of tree. Other graphs showed rate of loss of weight due to drying. All these graphs were compared.

Finally, one boy calculated the total leaf area on a tree. To do this, he used 0·1-inch squared paper, thus getting his introduction to decimals.

There were other measurements being made, too. The children had decided to measure the height of each tree, first using a stick placed against the tree and estimating how many times it would go into the height, then by means of a hardboard triangle on the end of a stick, as in figure 22. They measured girths and also diameters, noting the simple relationship. The girth at different heights was related to the height of the measurement from the ground, and hence indirectly to the vertical growth of the tree.

One group noticed the vegetation under the tree and compared it with that under others but, unfortunately, this study ended when the farmer applied weedkiller. It was noted, however, that nettles and chickweed grew under the trees, but not in the open; and that there were bare uneven patches under the conifers, and that these were related to the varying extent of the canopy which in turn depended on the prevailing wind.

One group collected insects from the foliage by rapping a branch smartly with a stick, or by shaking. These had to be housed and this meant making cages from cardboard boxes, muslin, and Cellophane. The children learned to recognize the creatures they collected and compared them with those they found on a dead tree stump. The eggs collected from the stump were kept and eventually proved to be those of a spider. From these collections, the children were able to observe life cycles in a number of cases.

Presently, Stephen made a collecting instrument from an empty 'squeezy' bottle and collected insects from the trunk and branches. David, on the other hand, was interested in timbers and collected and compared twigs from the trees. He also corresponded with the Forestry Commission, and started to enquire into the properties of different woods. For example, he investigated hardness by seeing how many strokes of the hammer were needed to knock a large nail into different kinds. He learned to tell the age of twigs by counting rings. To do this more efficiently, he decided to saw a twig at an angle. He then discovered that the cross-section was elliptical instead of circular. The teacher used this as the basis for a general class discussion on shapes, especially those obtained by sectioning and also by rotating common objects such as pennies, books, and cards. David also noticed that the distance between rings varied from year to year and wrote away for details of weather records over the years to see if there were any connection.

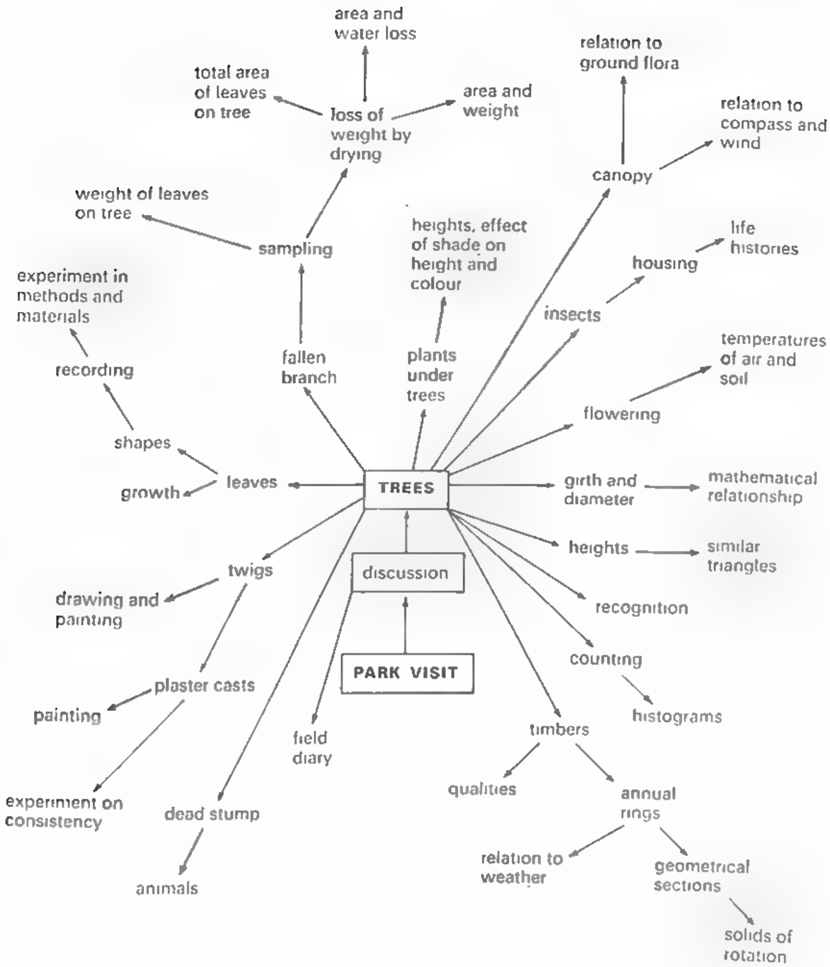
The study had now reached a stage where it had a bearing on all parts of the school curriculum. The children did a great deal of computation and making graphs, and learned

numerous new words. Philippa compiled a dictionary. Another group collected poems about trees and then took to writing their own. Art work grew out of the twig and leaf records. Leaves provided stencils for patterns and the children made leaf and bark rubbings. The teacher brought into the classroom a fantastically shaped piece of wood that he had found and they used their imaginations about it eagerly, discovering weird monsters in the shapes. The study also gave rise to geography, added to the children's interest in the history of their village, the reign of Charles II, the wood used to make medieval longbows, and so on, and it helped to make plainer some of the stories the children were learning in religious instruction.

Sometimes the children made tape recordings describing the work they were doing. They exchanged these with tapes made by a similar school some thirty miles away, and this led to one school visiting the other.

The study was brought to a halt by the summer holiday, but with the beginning of the autumn term, the work continued with an investigation of the relative efficiencies of various windborne fruits—sycamore ash, etc. —which had been collected throughout the summer. The method the children used was to liberate them from a height to see how far they would be carried. They did this from the top of the church tower, the only place which was both high and open to the wind on all sides. During their visit to the tower, the children had to climb through the belfry and the clock room. They also found a set of handbells, and for a short time interrupted their experiments to study sound. The worn steps of the old church tower started an enquiry into why stone wore away.

FIG. 22. Estimating the height of a tree.


area and
water loss
total area
of leaves
on tree
loss of
weight by
drying
area and
weight
relation to
ground flora
relation to
compass and
wind
canopy
weight of leaves
on tree
sampling
heights, effect
of shade on
height and
colour
life
histories
housing
insects
experiment in
methods and
materials
recording
fallen
branch
plants
under
trees
temperatures
of air and
soil
flowering
shapes
leaves
growth
TREES
girth and
diameter
mathematical
relationship
heights
similar
triangles
discussion
twigs
drawing and
painting
recognition
counting
PARK VISIT
plaster casts
painting
histograms
field
diary
timbers
qualities
annual
rings
experiment on
consistency
dead stump
animals
relation to
weather
geometrical
sections
solids of
rotation

13 Stone-age art materials

Class	7-11 years. Full range of ability
Class number School roll	19 boys and girls 31
Term	Autumn
Building	Built in 1835. Post-war improvements have done little to improve a small, dismal, and generally unsatisfactory building.
Classroom	Former school room divided by a partition into two classrooms. Modern furniture within a limited area.
School environment	Set on the edge of a pleasant village green of a south Northumbrian upland settlement.
Local setting	North-east England. A sheep farming area. Nearby there is a large sandstone quarry and a small privately run coal mine.

The headmaster of this small school is a keen astronomer and intended to make astronomy his starting point. Instead, the class became involved in a discussion on the Stone Age. The paintings of the period were mentioned, and David asked, 'What did they paint with?'

The only sources of paints, it was decided, must have been animal, vegetable, or mineral, and at once some of the older children realized that they, too, might use natural materials to draw and paint. Could they try? The teacher agreed. Here was an opportunity for experimentation.

The first material the class wanted to make was a familiar one—charcoal. They cut privet twigs from a hedge in the school garden, but when these were held in a flame the product was ash, not charcoal. The class decided to try heating some of the twigs in a tin. They used a dried milk tin with two holes in the lid, and this—with twigs inside—was placed in the open end of the classroom stove. The apparatus is shown in figure 23.

Soon smoke emerged from the holes in the lid. Just as Carol asked, 'What kind of smoke is it?', one of the older boys lit it. Seeing this, Peter asked, 'Can we try this with a piece of coal?'

When the smoke from the privet twigs diminished, the tin was removed from the 'furnace' and replaced by another tin containing pieces of coal. As in the case of the twigs, strong-smelling 'smoke'—appeared at the holes. The children immediately lit it. Carol suggested that although there was a smaller amount of coal than of twigs, more smoke had been driven from the coal. Some of the class referred to the smoke as gas, but Pat still regarded it as smoke when she asked, 'Would the balsa that the boys use for making

models, being so light, give off less smoke than the first lot of twigs we used?'

Obviously the way to find out was to try. A considerable quantity of balsa wood was placed in a third tin for treatment. Again smoke came off, but this time the children found it difficult to light. At this point Carol pursued her earlier idea; she contended that the denser the substance, the greater was the amount of smoke released. (She actually used the word 'denser' but there is no knowing what it meant to her.)

When the children opened the three tins, they found:

Tin 1: charcoal sticks.
Tin 2: coke, plus tar on inner walls of tin.
Tin 3: ash, plus a few pieces of soft charcoal.

Colin immediately decided that the harder the material burnt, the harder was the substance left in the tin.

In fact, Carol's and Colin's hypotheses were not tested: attention now turned to the privet charcoal. Dorothy wanted to use it for copying pictures of Stone-age cave drawings.

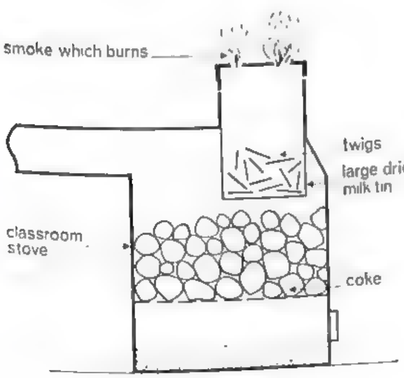


FIG. 23. Apparatus for making charcoal in classroom stove.

But she soon found charcoal was very hard and scratchy and gave a poor black. Privet charcoal was ruled unsatisfactory and other kinds of wood were treated. Of those heated in the tin, willow yielded the best charcoal. The willow sticks retained their original shape; when used on paper they made a firm black mark. The children were delighted with the willow charcoal and made drawings of various subjects with it.

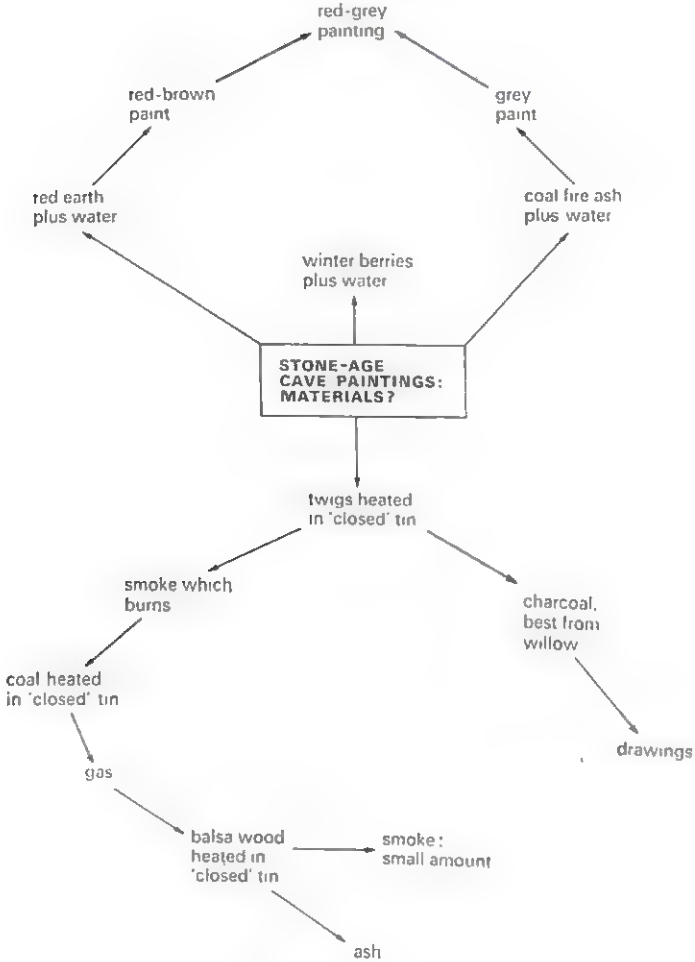
While most of the class continued to draw with charcoal, one group attempted to make paints from winter berries. It was early December. The brightly coloured berries, which were hard and not juicy, were macerated in water, but every variety tested failed to produce any usable paint. Clearly Stone-age man had not passed winter days in climates like ours painting with paints made from berries gathered in December. But it was possible that the berries of summer and autumn (for example, the blackberry) had been source materials.

David was responsible for the next development when he brought to school a large bag of 'red stuff' he had found on the site of an old lime kiln near his home. The 'red stuff', possibly a red ochre, was heated in a tin and did not change. When mixed with water the red earth gave a rich red-brown stain to paper.

The following day two children arrived at school with white ash carefully collected from their coal fire grate. This they ground and mixed with water to produce an acceptable grey paint.

With charcoal and two paints available, several paintings were made. One is shown in plate 5. Although the children were restricted in their choice of colours, they were satisfied that they were working with natural colours that could have been used by their Stone-age ancestors.

This investigation took only a short time. It began in the second half of November and ended amidst Christmas festivities.


red-grey
painting
red-brown
paint
grey
paint
red earth
plus water
coal fire ash
plus water
winter berries
plus water
STONE-AGE
CAVE PAINTINGS:
MATERIALS?
twigs heated
in 'closed' tin
smoke which
burns
charcoal,
best from
willow
coal heated
in 'closed' tin
drawings
gas
balsa wood
heated in
'closed' tin
smoke:
small amount
ash

14 River and woodland visit

Class	**7-15 years. Full range of ability (Two-teacher school, not reorganized)**
Class number School roll	23 boys and girls 43
Term	Autumn
Building	Modern two-classroom building.
Classroom	Display and working surfaces available. No gas or water in room. Working area adequate.
School environment	Set in a farming area.
Local setting	Northern Ireland. Rural area near large city.

The class visited a small river near the school. They approached it through a wooded area where fungi, coloured leaves, and chestnuts attracted attention. Little was found in the river, but specimens from the wood were brought back to the classroom.

Anne asked 'Why do the horse chestnut fruits have prickles?' When she was asked for her ideas on the subject, she said, 'They are to protect them.' A discussion followed as to how this could be decided. One child suggested dropping some horse chestnuts from the school roof. There were objections to this because the fruits would fall on asphalt; so they were dropped from a high ladder on-to grass. Records were kept of those that broke and those that did not, from which it was quickly seen that the prickles did not prevent breaking.

They measured the thickness of the skins and found that the horse chestnut fruits with thin skins broke more easily than those with thick skins. The children returned to the tree to see from what heights the chestnuts fell, and tree heights had to be measured. Agnes, who was fifty-six inches tall, stood at the base of the tree while the others estimated from a distance that the tree was six times as tall. A quick calculation showed that the tree was twenty-eight feet high.

The children dropped seeds, leaves, and tennis balls from the roof of the school. A gentle breeze carried away some of the seeds. This led to discussions of seed dispersal and of the way objects fall. One child used the seconds hand on a watch to time falling chestnuts; he was convinced that the seeds which fell faster were heavier. To check this idea he made a spring balance. He also dropped other things of different weights, such as stones, and timed them too.

The interest of other children focused on

the problem of weighing. They constructed a variety of weighing machines (see figure 24) and calibrated them. A steelyard which had been made by the teacher and left in the classroom interested one group of boys. They weighed things and drew a graph showing the relationship between weight and the distance from the counterpoise to the fulcrum.

Some eight-year-olds collected worms. They drew and painted pictures of worms, handled them, counted how many there were in spadefuls of loam and clay soils, and observed and timed the movement of worms over a distance of a yard. They saw the saddle, counted the rings, and looked closely at the worm's mouth. They guessed that worms ate the soil; and they discovered worm casts and found worms' 'eggs' (meaning cocoons). The saddle was suggested to be the source of the eggs, but this idea was not followed up. Eventually they made a wormery and watched the mixing of the various layers of soil.

The study of worms' 'eggs' led them to seek information from books about the eggs of other creatures. Here there was mention of egg shapes and how these were related to clutch size. In particular, the children studied hens' eggs, noting their shape and calling it a parabola. The strength of the shells was investigated by squeezing the eggs along the long axis. They found that they could not break them.

Some children brought sand samples from the river and these evoked comments on rocks and rock formation. Sandstone was examined and seen to be composed of sand grains cemented together. The children even tried to make sandstone by submitting a small pile of sand to a few pounds' pressure.

A spectacular sunset led to a series of investigations. Ray, aged nine, painted it and then described it:

> 'First it was whole, then it went stripy, then it went half, then it went quarter, then none at all and then all fissy pink.'

His painting depicted this sequence of events. He said that in the old days people used the sun to tell the time; if he could have a telescope he would set it up and get 'a picture of the sun on a piece of card'. He thought he could trace its outline each day and he would then see the sun change in size. This change would occur, he believed, because we are not always the same distance from the sun. An astronomical telescope was brought to school and Ray and some other children started to work. Focusing the image on the paper required adult assistance at first. Various coloured cards were used and the group decided that the best colour to show up the sun was green. Black dots were seen on the image of the sun. At first they suspected dirt on the paper and examined it closely. Next they cleaned the lenses of the telescope. But the spots remained. At this point the teacher told the children about sunspots.

Work on sundials started. They drew chalk lines on the school playground to mark the shadow of one leg of the telescope tripod. They did this at hourly intervals throughout one morning. The following day they hoped to do the same, but overnight rain had washed away all traces of the chalk lines. As a result, the sundial work was transferred to the classroom. They used a rectangular board with the school bell on it. The position of the bell was marked in chalk, and the position of shadows was drawn in at hourly intervals. The board was aligned along one of the divisions between floor boards so as to maintain a correct orientation. Changes in the position of shadows at similar points in time were commented upon. When the telescope was used for looking at terrestrial objects, these were seen to be inverted. This aroused interest in lenses. Ray made a remarkable series of optical instruments using convex and concave lenses, Plasticine, and balsa wood. These included telescopes, microscopes, and field glasses (which he called a 'seeing-scope'). He called bi-convex lenses either thin or thick lenses, and said they went 'fuzzy' (holding the lens at arm's length and looking through it). He called bi-concave lenses clear lenses.

In showing the working of his instruments he would talk about focusing. To focus, he arranged one lens so that it could slide along

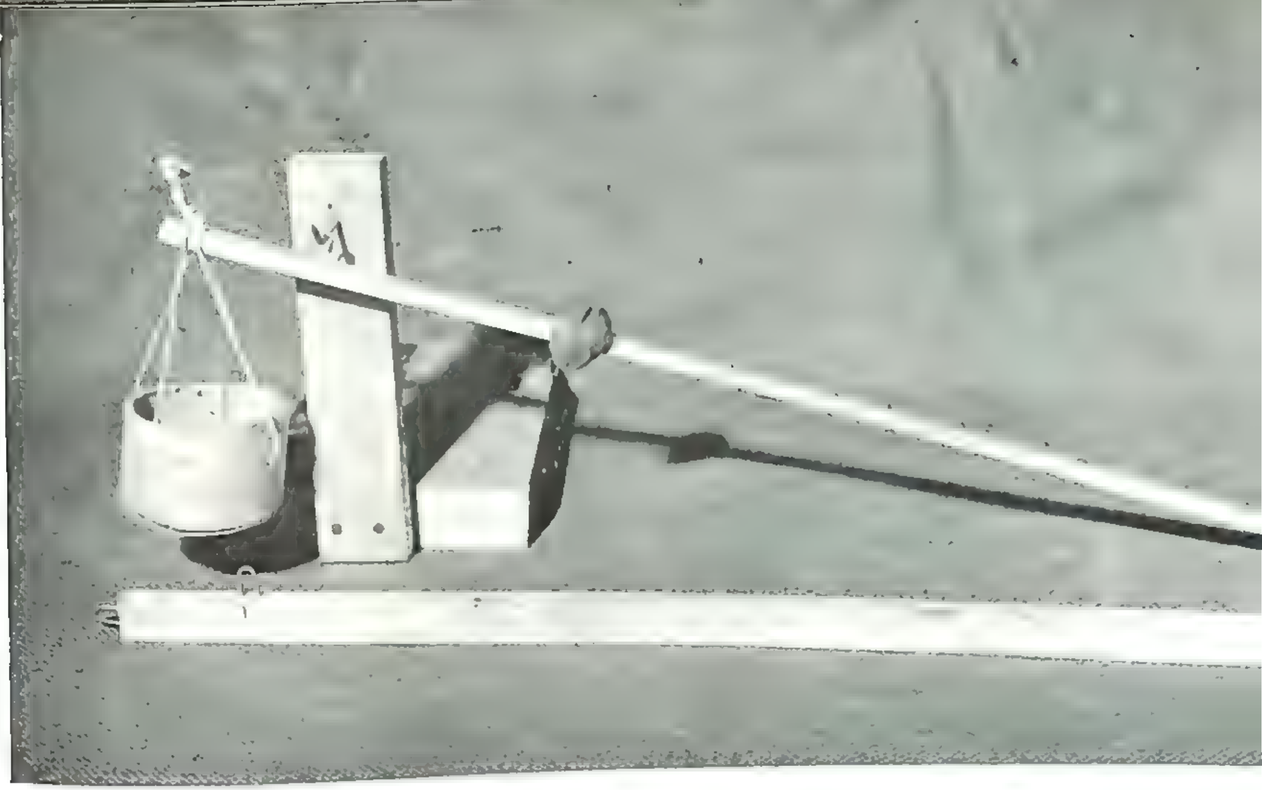


FIG. 24. One of the children's weighing machines.

FIG. 25. Ray's optical apparatus including devices for focusing lenses.

the balsa wood. His instruments are shown in figure 25.

The telescope was used in the evenings for observing stars and planets. The two objects which created most interest were the moon and Jupiter. The moons of Jupiter were seen, and after a number of observations their movements were noted. The number of moons on each 'side' of the planet changed. One eight-year-old girl said it might be Jupiter moving, or maybe the moons moved. A few older pupils tried to work out the periods of Jupiter's moons.

Later in the term, when working with the spring balances, the pupils studied up-and-down vibrations. Some counted the number of vibrations in thirty seconds. The teacher saw that the balance was not far removed from a pendulum. He made one from string and heavy steel washers. The swings were timed, and experiments were done to discover what happened when the length of the pendulum and weight of the washers were changed. At this stage some boys attempted to make a 'pendulum clock'. Some of the older boys were interested in magnetism and electricity and worked with cycle lamp batteries and bulb holders. They wired circuits which linked two and more bulbs. They also made switches. One two-way switch was later used to wire a doll's house made from an onion box.

After a discussion on finding direction from the stars, pocket compasses were introduced. Some of the children made electromagnets, and later constructed a model railway signal.


weighing
methods of weighing
levers
vibrations of spiral spring
pendulums
clocks
microscope & binoculars
making terrestrial telescope
making astronomical telescope
sundials
sunset
sun image on card
sunspots
VISIT TO RIVER AND WOODLAND
worms
soil
clay
loam
sand
examination by binocular microscope
study of rocks
formation of rocks
strength of materials
chestnuts & prickles
dropping: thin skins broke
height of tree
other objects falling
curves shapes
eggs
seed dispersal
stars observed moon Jupiter
movement of moons
magnetic compass
magnets
electromagnets
electricity
circuits
electric bell

15 A schools broadcast

Class	**7-8 years. Full range of ability**
Class number School roll	34 boys and girls 283
Term	Spring
Building	An attractive single-storey building dating from the early 1930s. Classrooms are pleasant and convenient places in which children can work. Folding windows give direct access to garden and playground.
Classroom	Large, bright room with modern fittings, including water. One of two rooms comprising an annex. Plenty of display space both vertically and horizontally, and cupboards for storage of materials.
School environment	The school is very well sited on a wooded hillside, between two housing estates (one established for thirty years, the other for ten years). School field is adjoining, on the site of a filled-in quarry.
Local setting	North-west England. On the outskirts of a thickly populated industrial town. Easy access to rural areas.

After listening to one of the B.B.C. radio series, *Stories from world history*, the children started a lively discussion about the Romans. The teacher decided to let them follow their interests.

The pupils did research in books and paid a visit to a local museum to look at the Roman relics. Before long, two lines of scientific enquiry emerged. David asked how the Romans heated their homes; Neil started a discussion on time and how it was measured. He observed that the numbers on the face of the classroom clock were Roman. A discussion followed David's query and the children visited the school boiler house, where great interest was shown in the temperature dial. Some of the children explored the hot pipes in different parts of the school. Three of the boys wanted to make a model of a Roman villa to illustrate the heating system. The double floor presented some problems but, after talking with the teacher, they managed to make a satisfactory model. Only Joyce was interested in pursuing heating. She took temperatures outside and compared them with the classroom temperature. This did not go any further as a student took over the class at this point.

The work on time and its measurement proved much more productive and soon became experimental. For a time, it involved the whole class. A clock 'investigation' table was set up at the back of the room. Children brought old watches, an alarm clock, a cuckoo clock, an egg timer, candles. The teacher added some reference material—books and pictures, and later a metronome and stop-clock. Derek, who became very interested in reading and writing about clocks, was asked if he thought he could make a water clock. He began experimenting. Interest snowballed, and everyone wanted to make clocks. An S O S to the rest of the school for empty plastic containers of all kinds met with a quick response, and there was plenty of material for all.

The children formed their own groups according to the kind of clock they wanted to make. John was the leader of a group of six which experimented with water clocks. He was very interested and organized his group into a good working team. They produced various kinds of water clocks, each timed at a different rate (figure 26). The teacher and John wondered if the group could produce one which would last for the duration of a lesson. Two days later he announced that he had made one which lasted fifteen minutes, the length of playtime. The teacher asked how he had made it, and he replied, 'Well, I found a little hole made the water come out too slow and a big one made it come too fast, so I got one in between.' When asked if he could make it go twice as fast, he said it could be done in two ways, by making the hole twice as big or by putting half as much water in. While John was away from school for a week, Neil took over the group. John's influence was apparent in Neil's work, he too having the same kind of understanding as John of the way the clocks worked.

Stephen, working on his own, announced that he had a sixteen-minute clock, which he made into an eight-minute one by using half the volume of water, timing it carefully by the clock on the wall.

Later Stephen was reading about water and came back to the classroom excited about

FIG. 26. Making water clocks.

FIG. 27. String and Plasticine pendulum.

how water 'disappeared'. He set up an experiment using two saucers of water, one of which he covered with paper. When questioned about this, he said, 'Well, it will show that the air and sunlight make water go faster.' His forecast proved correct, and he commented, 'It has gone quicker because the air could get at it.'

Margaret was investigating sand clocks. She attempted to make several, making the holes bigger each time and putting in less sand, but she was having trouble because the sand was lumpy. Eventually she went to the teacher, and the following conversation took place:

MARGARET: The sand doesn't go through the hole properly; it is too lumpy and stones keep stopping it.

TEACHER: How do you make the sand start going through the hole again?

MARGARET: By shaking it.

TEACHER: Does the stone go through the hole?

MARGARET: No, it stays in the squeezy bottle.

The teacher left Margaret to think more about this, and later discovered her very busy shaking sand through a small hole—in fact she was sifting it. She said, 'I am making the sand thin so that it will go through the hole easily.'

She continued sifting until she had what she judged to be enough sand for a clock. This time she was more successful, but even then the sand still did not flow steadily enough to make the clock work properly. She considered how to make a finer sieve.

Derek, who had sparked off all the experimental work on clocks, brought a book from the library to show his teacher a picture of Galileo's pendulum. 'Could you make a pendulum, Derek?' 'Yes, I would like to. Can Gordon help me?' The two boys made one from string and a ball of Plasticine and showed it proudly to everybody. Two days later Derek was 'playing' with his pendulum

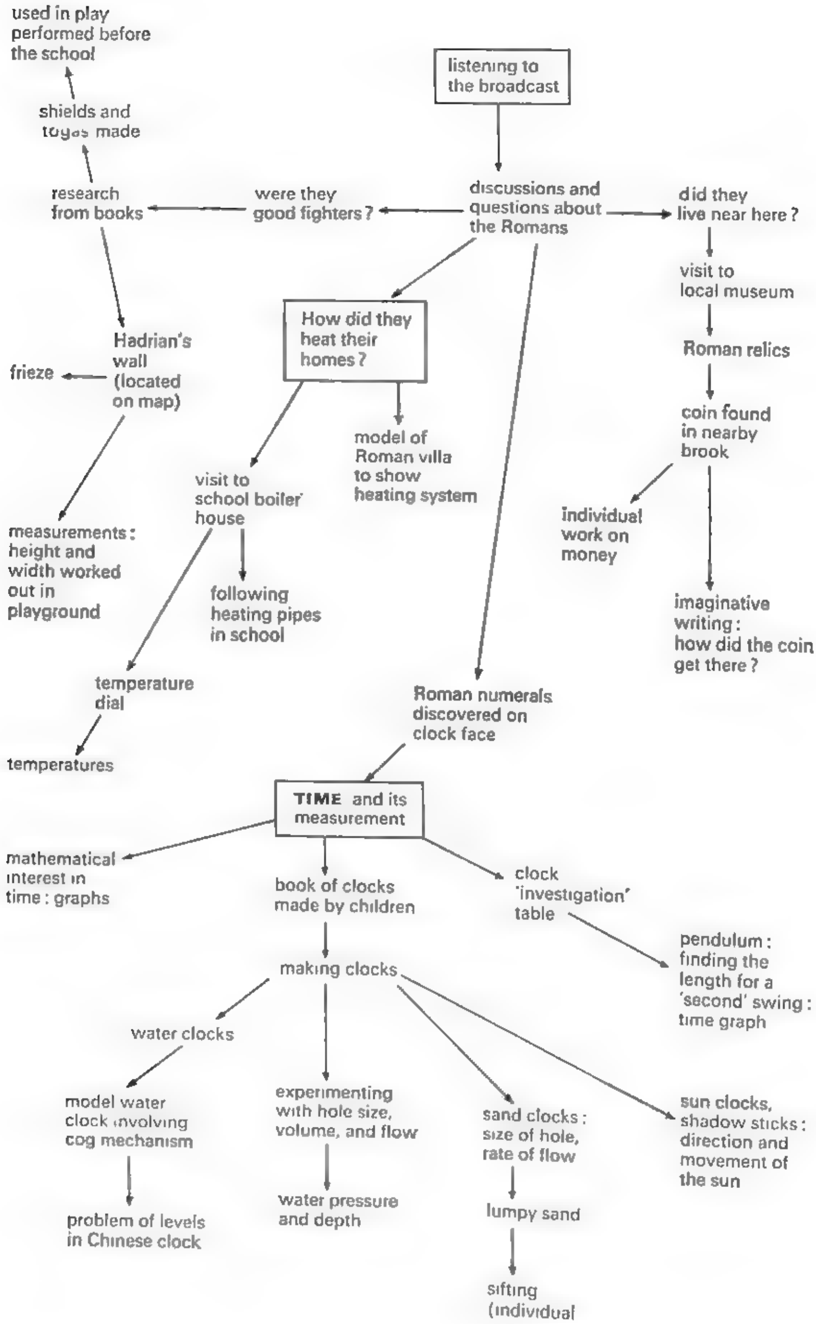
again, and his teacher asked him if he could make one which would keep the same time as the classroom clock. He fetched the metronome and stopclock from the clock table and said he thought he could. He set the metronome working, and, by trial and error, got it to tick sixty times in one minute (timed by the stopclock). He then began to swing his pendulum, at first using a short string. 'That should be right,' he said. The pendulum swung far too fast so he lengthened the string; he experimented many times but could not get it right. The teacher did not interfere. Later he found Derek measuring the string with a ruler. 'Three feet is too short and four feet is too long, so I'm trying to find out what it should be,' explained Derek. Later he came to tell the teacher: 'Three feet three inches is the right length—it swings right now.'

To get a clear swing for his pendulum during these experiments Derek put two chairs on top of two tables and stretched a string across between the chair backs from which he suspended his pendulum. He found it necessary to get friends to sit in the chairs to hold the string taut. His pendulum is shown in figure 27. The teacher wondered if a bigger piece of Plasticine would make any difference, Derek said, 'I think it will go faster'. He made the bob bigger and some time afterwards he came and said, 'It doesn't matter about the size of the Plasticine.' Derek asked if he could make a graph and that was how he recorded his results.

Some time after this, nearly at the end of the term, Derek set up the pendulum again and was worried because the results were 'different': the pendulum was 'bumping'. He tried altering the weight, although he had discovered earlier that this did not make any difference, and then suddenly he discovered the cause—the two chairs supporting the string were not exactly opposite each other! He repeated a number of swings and checked his graph to his own satisfaction.

One boy, working with water clocks, made three holes in the sides of the container, and the children were fascinated to see the different ways in which the water came out. One of them explained it by saying that there was more water 'pressing down' on the bottom hole.

During the last five weeks of the term a student took over the class and the children made a fairly heavily directed study of water, using assignment cards for experiments. The teacher noted that the children tended to ask fewer questions and seemed to lose some of their enthusiasm as time went on. At the end of term, he made this comment: 'The experiences the children have had this term have given them more real learning situations and zones of immediate interest than I could ever have hoped for. This experiment has proved to me the real value of the less structured approach and the way in which the children have worked is the criterion.'


used in play performed before the school
shields and togas made
research from books
listening to the broadcast
were they good fighters?
discussions and questions about the Romans
did they live near here?
visit to local museum
Roman relics
coin found in nearby brook
individual work on money
imaginative writing: how did the coin get there?
Hadrian's wall (located on map)
frieze
measurements: height and width worked out in playground
How did they heat their homes?
model of Roman villa to show heating system
visit to school boiler house
following heating pipes in school
temperature dial
temperatures
Roman numerals discovered on clock face
TIME and its measurement
mathematical interest in time: graphs
book of clocks made by children
clock 'investigation' table
pendulum: finding the length for a 'second' swing: time graph
making clocks
water clocks
model water clock involving cog mechanism
problem of levels in Chinese clock
experimenting with hole size, volume, and flow
water pressure and depth
sand clocks: size of hole, rate of flow
lumpy sand
sifting (individual
sun clocks, shadow sticks: direction and movement of the sun

16 The sea shore

Class	**7-8 years. Upper of two streams**
Class number School roll	35 boys and girls 200
Term	Summer
Building	Built in 1920's. Previously used for older children.
Classroom	Pleasant and not overcrowded. Modern furniture, flat-topped desks and separate chairs.
School environment	School overlooks the sea.
Local setting	North-east coast of England. School serves a small town containing both a mining and a fishing community.

The children tried to visualize the Breton fisherman's prayer, 'Dear God, be good to me; the sea is so wide and my boat is so small.' Emma called out, 'I can see a big sea with a little boat on it.' This started a discussion about the moods of the sea. Neil stated, 'When it's rough it brings the cliffs down.' Others expressed doubts about this so they visited the headland. Jacqueline, looking at the great cracks, and pieces of rock ready to fall, said, 'I know, the rain gets in the cracks and washes it out.' Neil thought that if the rain froze it would break the rock off: 'My mummy's milk froze in the winter and pushed the top right off.' Gradually they pieced together the story of falling cliffs. Later, they wrote about their expedition and added their own illustrations. Many children drew maps of the bay, and Neil produced a very good sketch map.

The children were eager to visit the shore. On the next fine morning soon after high tide they set out. Few settled down to do any one thing. Most moved from rock pools to sand dunes and back again, attempting to see everything at once. The teacher, anticipating this, had suggested that they look for anything of interest. This left them free to settle in their own time and to examine things which interested them.

Many of the children brought their finds to show her before putting them into plastic bags. Questions flowed:

'What is this?' (eroded concrete)
'Will sea-coal burn?'
'Don't anemones sting?'
'Is this a bit of a cup?'

The children's observations invited confirmation or questions from the teacher:

'This is a crab's leg.'
'Look at this shell. It looks like a spinning top.' (It was, in fact, a top shell.)
'I've found a bit of a lobster pot.'

When they returned to their classroom and spread out their collections they had a wide range of specimens including two shore crabs, several sea anemones, pebbles, sea shells, seaweed, eroded brick and concrete, smoothed glass, sea-coal, rusty iron, cork, and parts of crabs' skeletons.

The teacher relied on the children's questions and discoveries to be a guide to their interests. The work evolved around them. The children worked mainly in groups and there was much individual work. At times the whole class became interested in a child's discovery and would follow it up together. This happened when Emma pressed her seaweeds between sheets of newspaper as she had previously pressed wild flowers. The idea captivated the others; they tried pressing seaweeds in various ways. Finally the teacher showed them how to use blotting paper and muslin to achieve good results. They were so pleased with them that they decided to make a class book telling where each was found.

Meanwhile, children pursued their individual interests. Neil had collected a fossil and a piece of soft wet wood from a log on the shore. He made a drawing of the fossil, then put it away carefully, intending to build up a collection. He counted the annual rings on his wood, then weighed it. He wanted to find out how much water it contained, but couldn't think of a way to do it. Michael advised him to let it dry and then weigh it again. Soon others were weighing and measuring their specimens.

After finding attractive patterns in pebbles and sea shells, the children began to draw seashore patterns and built up a collection in a special book. Raymond discovered that he could make sand by rubbing two pieces of sandstone together. Some other children tried this, while some tried rubbing different kinds of stones. They found that very hard stones wouldn't work but soft stones could be ground down fairly easily. This led to discovering, with the teacher's help, about the origins of igneous and sedimentary rocks. Alan discovered that sea shells could be powdered to make shell sand. The different kinds of sand were poured into saucers, labelled, and set out on the investigation table for everyone to see. Emma commented, 'Sand is made from a lot of things'. They examined sand from the beach and quickly recognized pieces of brick, sea shells, and coal. The teacher suggested that they might like to collect stones to make other kinds of sand, but they had achieved their immediate aim, had written down what they had discovered, and were no longer interested. A brief study was made of the shape of the pebbles on the beach and an explanation sought. Melvin made a collection of pieces of brick in various stages of erosion from almost perfect bricks to small red pebbles. This was convincing evidence.

Graeme found a large oar weed (*Laminaria*) on the strand line. He was astonished at the strength of its stalk: the holdfast had been pulled off and the stalk had not broken. He decided to find out how much weight it would bear before breaking. He tied string around the holdfast and hung it up. Next he took a plastic cup, fastened some fine wire round it, and hung it at the point where the stalk met the fronds. He found that the weights which he needed were too big for the cup so he used a plastic bag instead. His apparatus is shown in figure 28.

Eventually, at a weight of 13 lb. 8 oz. the string broke and the seaweed fell to the floor. He drew a picture of his apparatus and wrote an account of what he had done. This completed, he showed no further interest in the project, 'which', as his teacher commented, 'seems to be typical of children of this age. Having satisfied their curiosity, they turn to other things.'

Keith examined the rusty metal which he had collected. He knew that only metals rusted, but wanted to find out which metals rust most quickly. He collected an assortment

of metal objects and left them in a jar of water for a fortnight. He concluded, 'Things with a lot of iron in them rust very quickly.'

Occasionally there were a few children who found nothing of interest among the objects which they had brought from the beach. When this happened, the teacher gathered them together and asked leading questions to stimulate discussion and curiosity. During one of these sessions, a great deal of interest was aroused by a piece of cork which Melvin had found. The children knew that it had come from a fisherman's net and that it was used because it floated. This led to experiments designed to find out which other materials would float. All of the children felt the upthrust of the water as they pushed pieces of wood under the surface, but only Neil was ready to go further than this and say, 'The weight of the wood must be the same as the water it pushes out.' How did he get to this? Was it from discussing it with his father?

The children's response to outdoor work changed continuously. At first they were excited and collected items indiscriminately. By the fourth visit they were setting to work much more calmly and methodically.

The rock pools were the centre of the children's interest for about four weeks. Seaweeds were collected and examined. Time was spent finding out whether bladder wrack floated because of the bladders or whether it would float without them. The function of holdfasts was discussed. Seaweeds were planted in pots of soil to see if their holdfasts would grow like ordinary roots. The teacher set out a collection of reference books and the children turned to these to find the names of their seaweeds.

They made two large pictures. The first showed life in a rock pool (plate 6). The children searched through piles of material until they found pieces which had the right texture as well as the right colour for making into seaweeds. They felt the seaweeds with their finger tips and their vocabulary grew as they searched for words to describe the textures.

A picture of the bay in summer was started

FIG. 28. Testing tensile strength of oar weed.

at Paul's suggestion. It showed a helicopter and a lifeboat rescuing a swimmer. The two pictures absorbed the attention of all the class. They also provided alternative activities for those who had finished their group work.

Aquaria were set up in the classroom. They were arranged like miniature rock pools, and stocked with creatures collected from the shore. The children were particularly interested in feeding habits. Susan wrote, 'When we are going to feed the anemone it would open its tentacles and wrap its tentacles around the mince and pull it inside of him.' Many discoveries were made. Small shore crabs were collected. Each was placed in a plastic container so that it could be examined easily.

The children offered them fish but they scuttled into the corners of the containers and refused to eat. Someone suggested that they might only eat when the tide was in, so water was poured into the containers and the crabs began to feed. This caused considerable discussion about tides and food. The children found a crab devouring a starfish in a rock pool. This brought home to them the struggle for existence on the shore. Their interest in these creatures prompted them to use reference books to find out more about them. After they had spent some time handling and observing the creatures and had had an opportunity to find out what they could, the teacher gathered the children around her and they pooled their knowledge. They pieced together the life stories of the animals with the help of the teacher, who filled out the knowledge which they had been able to glean for themselves. Their questions led to experiments, observation, or reading.

As the children gained experience they began to collect smaller and more elusive creatures like shrimps and bristle-worms. The teacher stimulated their interest by introducing puzzle games. She put tiny creatures into separate bottles and lined up the bottles in a row. Each was numbered and a card beside it said, 'Can you name these?' Only about a quarter of the children responded to this. They used reference books of their own accord for the first time.

Towards the end of the term the children became interested in the distribution of living things on the shore. Susan noticed that most sea anemones lived in cracks in the rocks. She used a piece of string to mark out equal samples in the cracks and on the top of the rocks. Altogether she counted seventy-four anemones in the cracks but only nine on top of the rocks. She commented, 'I think they lived in the cracks in case they got washed back by the waves.'

David and Janice found many starfish near the low-water mark but few further up the shore. They paced out the distance between high and low-water marks and at every four steps they counted the number of starfish in an area the size of their field boards. When they recorded this on a block graph it showed dramatically what they had discovered. This was their first contact with graphs. Next day they asked if they could make graphs of their own heights. Most children guessed that the starfish lived on the rocks near low-water mark because 'that's where the mussels are and starfish eat mussels'.

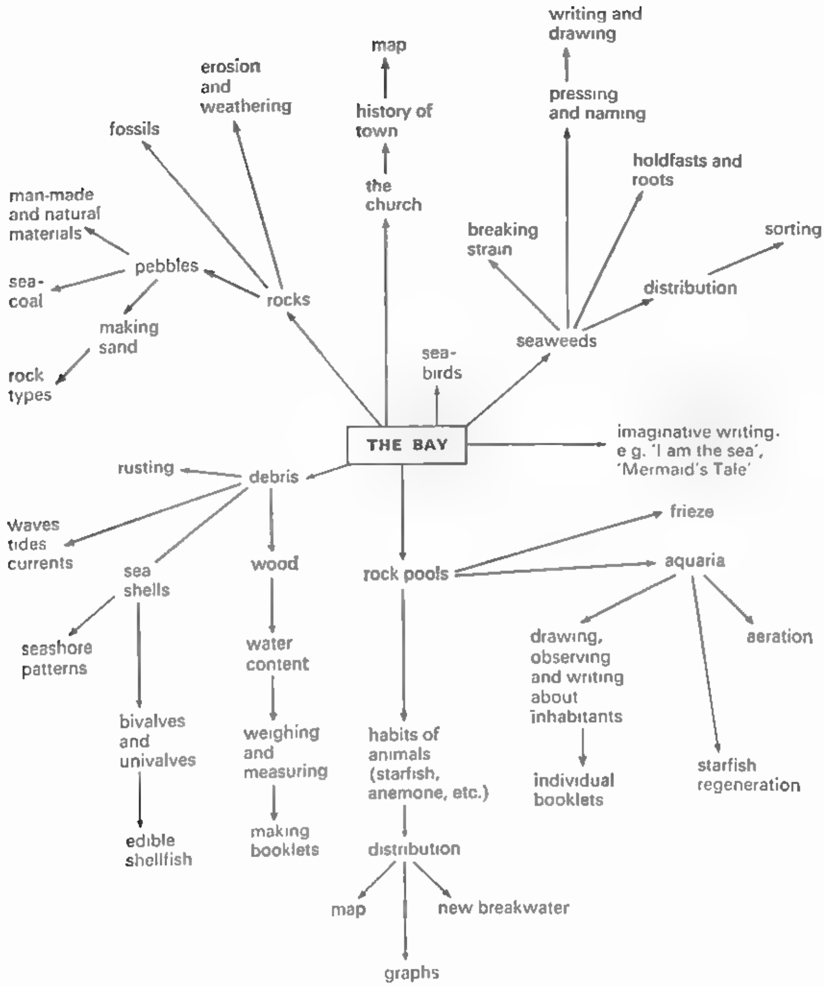
Seaweeds were collected and grouped by colour and by position on the shore. Valerie noted that no seaweeds grew on the shingle, probably because 'the stones would squash them when the tide came in.' The children also found out where hermit crabs, sea urchins, and various kinds of molluscs lived. They came across some creatures which they hadn't seen before—sea squirts and the sea anemone *Sagittaria troglodytes*, which are quite rare on this beach. All of these had to be examined and gently handled by every child. The teacher helped them to draw a huge map of the shore. Neil and Michael took command. On this they showed where to find things. This was, in effect, a simple distribution map.

Further studies arising from visits to the shore included experiments designed to find out more about waves, tides, and currents. The children put messages into four bottles and threw them into the sea. One was picked up by a Danish fisherman and another by two Danish children. This led to an exchange of information, picture postcards, and photographs.

Near the end of the term the children went to see which plants and animals had taken up residence on a new breakwater.

Beginning with a study of the church on the headland, they wrote about the village. At the teacher's suggestion, they made a large map of the town, showing the buildings near the bay and the shore on which they had worked. The buildings were made from paper and glued to the map.

The fishing boats interested the children, but in the ten weeks set aside for the project this was just one of the many interests which they had not time to follow up.


writing and drawing
map
erosion and weathering
history of town
pressing and naming
fossils
holdfasts and roots
the church
man-made and natural materials
breaking strain
sorting
pebbles
sea-coal
rocks
distribution
making sand
seaweeds
sea-birds
rock types
THE BAY
imaginative writing. e.g. 'I am the sea', 'Mermaid's Tale'
rusting
debris
frieze
waves tides currents
sea shells
wood
rock pools
aquaria
seashore patterns
water content
drawing, observing and writing about inhabitants
aeration
bivalves and univalves
weighing and measuring
habits of animals (starfish, anemone, etc.)
individual booklets
starfish regeneration
edible shellfish
making booklets
distribution
map
new breakwater
graphs

17 *Waste ground*

Class	**7-8 years. Full ability range**
Class number School roll	38 boys and girls 161
Term	Autumn
Building	Built in 1871
Classroom	Display space along two walls. Two display tables. One power point.
School environment	In the centre of an industrial town, next to a power station and rows of back-to-back houses.
Local setting	North-east England. Local industries include heavy engineering, textiles, chemicals, light industry.

The children visited a piece of waste ground near the school to see what they could find living there. They collected many small animals, wild flowers, autumn leaves, fruits, and seeds. On returning to the classroom, they examined their finds and talked about them. They showed great interest in the small creatures they had captured. A number of questions were asked:

'Why do insects run away when you lift the stones?'
'Can they see?'
'How does a spider spin a web?'

During the course of the discussion, the teacher lifted a willow herb from a jam jar. The movement caused some of the seeds to float off into the air. More questions were asked.

'Why do seeds go up instead of down?'
'Is that how seeds get spread, because they float away from one plant and just drop down?'
'What would happen if you planted a seed the wrong way up?'

Jim, looking at the elderberries which he had brought back, said, 'You can make elderberry wine.'

Some of the children wanted to follow up these questions, but others preferred to house their specimens and watch them. Groups were based entirely on the children's interests. There were usually five or six of them and the children were free to change from one to another whenever they wished.

Plastic lunch boxes were filled half way with moist soil and then set out attractively with plants and stones to provide homes for slugs, snails, and woodlice. A tall sweet jar was used to make a wormery. Caterpillars and spiders were housed in cages made from acetate sheets and cheese boxes. The children spent a lot of

time watching these creatures, handling them, and talking about them. They drew pictures of them and wrote about them. Those who could not read, a sizeable group in this class, asked the teacher to write down what they wanted to say. They copied it underneath their pictures. Thus the children's skill with language benefited directly.

There was a great deal of careful observation. Geoffrey, in his drawing of a slug, showed tiny bubbles in the slime covering its skin. These were so small that they could only be seen with a lens.

Different foods were placed in the containers to see which would be eaten. The children were surprised to find that the snails ate bread.

Stephen, a slow learner, brought nothing back from the visit; he had collected a single bunch of elderberries, but ate them on the way home. He watched the other children housing their specimens but he said little. The next day, however, he brought to school two slugs and the pupa of a large white butterfly which he had found in his father's allotment. He asked for a magnifying glass and made an extremely good sketch of the pupa. During the weeks that followed, he watched the caterpillars, slugs, and centipedes whenever he could. He sketched them and wrote about them. He was very excited in the spring when the imago emerged from the pupa.

As a result of their observations, the children were able to find out about the life histories and habits of several small creatures. Those children who wanted to write their own booklets about their visit to the waste ground worked alone. They wrote about their finds and drew the specimens which they had collected.

David and Geoffrey sowed the cornflower seeds which they had gathered from the waste ground. They also sowed acorns in different positions to see if they would grow.

A large group of children, recalling Jim's remark that wine could be made from elderberries, asked if they could try to make some. The teacher felt that this might not be very productive but agreed to help them, hoping that this work might develop into studies of boiling, evaporation, or fermentation. The recipe gave the quantity of elderberries in pints. When the children had measured out a pint of berries they tipped them onto the scales to see what they weighed. Kim and Lea wondered how many they had picked to make the wine. They estimated the number after counting how many were needed for one-fourth of a pint. They noticed that the number of berries on a head varied from as few as nineteen to as many as one hundred and fifty-seven, but decided that most heads bore about sixty.

While the berries were boiling, the children watched the steam condense on a cold pan lid. They asked about the evaporation and condensation of water, and discussed the differences between steam and smoke. After boiling the juice was strained through a clean tea towel. The children were interested in the process. They wanted to feel and examine the pulp which was left, but most of all, they wanted to look closely at the tea towel, which had been dyed a deep purple colour. This was the beginning of their interest in making and using vegetable dyes.

Some of the elderberry juice was poured into a jar and the teacher found an assortment of materials for the children to dye. She suggested that they should try dyeing them in different ways to see which was best. They all began by soaking material in cold dye; then they boiled pieces in dye. One or two tried rubbing berries on the cloth. Patricia dipped her fingers in cold dye and printed a pattern on a piece of paper with her fingertips. Others copied the idea.

The children noticed that cloth which had been boiled in the dye was the deepest shade of blue. They thought that the longer they boiled the cloth the deeper the colour would become. To test this idea they cut a number of small pieces from a length of white cotton and put them all into a pan of dye. Pieces were removed after they had simmered for five minutes, ten minutes, twenty minutes,

and half an hour. When they had dried they were compared.

The teacher now suggested that they should see how firmly the dye was fixed. The children tried to remove it from the cloth. Pieces of cotton which had been boiled in dye for ten minutes were used. Some were washed in cold water, others in hot water, and the remainder in hot water to which detergent had been added. After washing each piece thoroughly, the children dried them on radiators and compared them with a piece of clean cotton. The lightest sample was one washed in hot water containing detergent. As it was still a greyish colour the children concluded that the dye had not been completely removed.

This led to further attempts to find ways of removing the dye from material. Clothes which had been boiled for different lengths of time were washed to find out if boiling for a long time made the dye more permanent.

The children invented their own recipes for making dyes from onion skins, pine cones, walnut shells, and beetroot which the teacher had provided. By varying the quantities and the length of boiling time, they were able to produce different concentrations. Samples were poured into small glass bottles. When these were displayed against a white background the differences in shade could be seen clearly.

A small group of children became interested in the changes of hue which occurred when coloured materials were dyed with elderberry dye. A light green material, for example, became a much darker green. Billy, commented on this: 'That's how I get a deeper green in my paint box. I mix in some blue.' The teacher encouraged them to pursue their interest in mixing colours and gave them coloured Cellophane and some bicycle lamps, saying that they might find them useful.

They began mixing colours from a paint box, but soon they took up the coloured Cellophane. They used it in a variety of ways, sometimes looking at coloured objects through it, then overlapping two different pieces and looking again. Also they covered pieces of coloured cloth with it so as to observe changes in appearance. Finally, they used it to make filters for the bicycle lamps so that they could experiment with coloured lights.

While the children were using the bicycle lamps, Doreen remarked, 'There are different kinds of light, aren't there?' She hunted for information about gas lighting, and wrote an interesting account of how her father, who was employed by the Gas Board, looked after the street lamps.

Lea, who had been washing dyed materials, started a new series of investigations by asking, 'What could you put in the dye so that it won't wash out of the cloth or wool?' The whole class discussed the problem and these were among the suggestions which were offered:

ELAINE: Add some ink to the dye to make it stronger.
JEAN: Add some water with paint in it.
DOREEN: Put some salt in.
DAVID: Put some crystals in. You can make crystals with a chemistry set.
JIM: Mix two dyes.

They decided to test some of these ideas, but first the teacher suggested that they ought to find out which of the substances to be added to the dye would dissolve in water. They tried a number of substances including sugar, salt, flour, coffee, Epsom salt, chalk, cocoa, and sand. When some of them did not dissolve in cold water, Jim suggested that hot water might be better. This was tried. Geoffrey thought that it might be a good idea to mix a substance which did not dissolve with one which did, to see if this would persuade it to dissolve. When this did not produce the expected result, the children concluded that certain substances would not be of any use.

At this point, Christine, who was trying to dissolve powdered chalk in hot water, wanted to know how she could get the chalk out of the water again. David promptly said, 'Do what we did when we made the elderberry wine. Pour it through a cloth and see if we get it back.' They discovered that the insoluble

substances could be recovered by filtering, but those which dissolved could not.

Some of the children now turned their attention to the problem of recovering the soluble substances from their solutions. They poured salty water into a tin lid and warmed it with a spirit lamp.

This experiment was cut short when Kim arrived at school the next morning. She had discussed the problem at home and had brought a bottle of alum crystals, explaining, 'My brother says that if we're going to dye materials properly we'll need these.' The children immediately wanted to know how crystals were made and how to use them to make dyes fast. A booklet about vegetable dyes* provided an answer to the second question. Soon they were dissolving the crystals in water and using the solution as a mordant.

No one could find out how crystals were produced. The teacher showed them, by making a saturated solution and suspending a piece of thread in it. The crystals which formed were used to seed a fresh solution. The children wanted to try this for themselves, and worked mainly with alum, common salt, and Epsom salt. They used hand lenses and microscopes to examine the crystals which they produced and, at the teacher's suggestion, made large paintings of what they saw.

The different kinds of cloth which the children used for dyeing were interesting in themselves. Two groups of children investigated some of their properties. It all began when they discovered that a piece of knitted Courtelle would stretch when it was pulled. Other materials were examined to see if they would do the same. The children discovered that knitted materials stretched more than those which were woven. They made a large wall chart showing how different materials compared. With the aid of lenses, they examined materials as they were being stretched to see what happened.

Two boys had gone on examining the Courtelle and found that narrow pieces stretched more than wide pieces. For example:

a 6 in. piece 1 in. wide stretched $2\frac{3}{4}$ in.
a 6 in. piece $\frac{1}{2}$ in. wide stretched $3\frac{1}{4}$ in.
a 6 in. piece $\frac{1}{4}$ in. wide stretched $3\frac{1}{2}$ in.

One of the boys remarked, 'We could see if thin wool will stretch further than thick wool,' but this was not followed up.

The children examined different kinds of cloth and discovered the difference in appearance between knitted and woven materials. They saw that some were much more closely woven than others. They sketched the pattern of the weave of different materials. The children tried pulling out threads and found that in some woven materials they pulled out easily, while they were much more firmly anchored in others. Knitted materials pulled out completely, but only the weft pulled out of woven materials.

The children asked if they could make cloth, so they dyed some wool with onion skins and the teacher showed them how to weave on simple card looms. Many of them could not knit and learned to do this at the same time. Then they were able to compare the cloth which they had woven with what they had knitted from the same ball of wool, and to determine which would be better for making various garments. While Yvonne was search-through a book for information about weaving, she found a picture of Egyptians weaving on a simple loom. She made a large collage picture of the scene. At the teacher's request, she used wood and string to make a loom like the one in the picture so that it could actually be used for weaving.

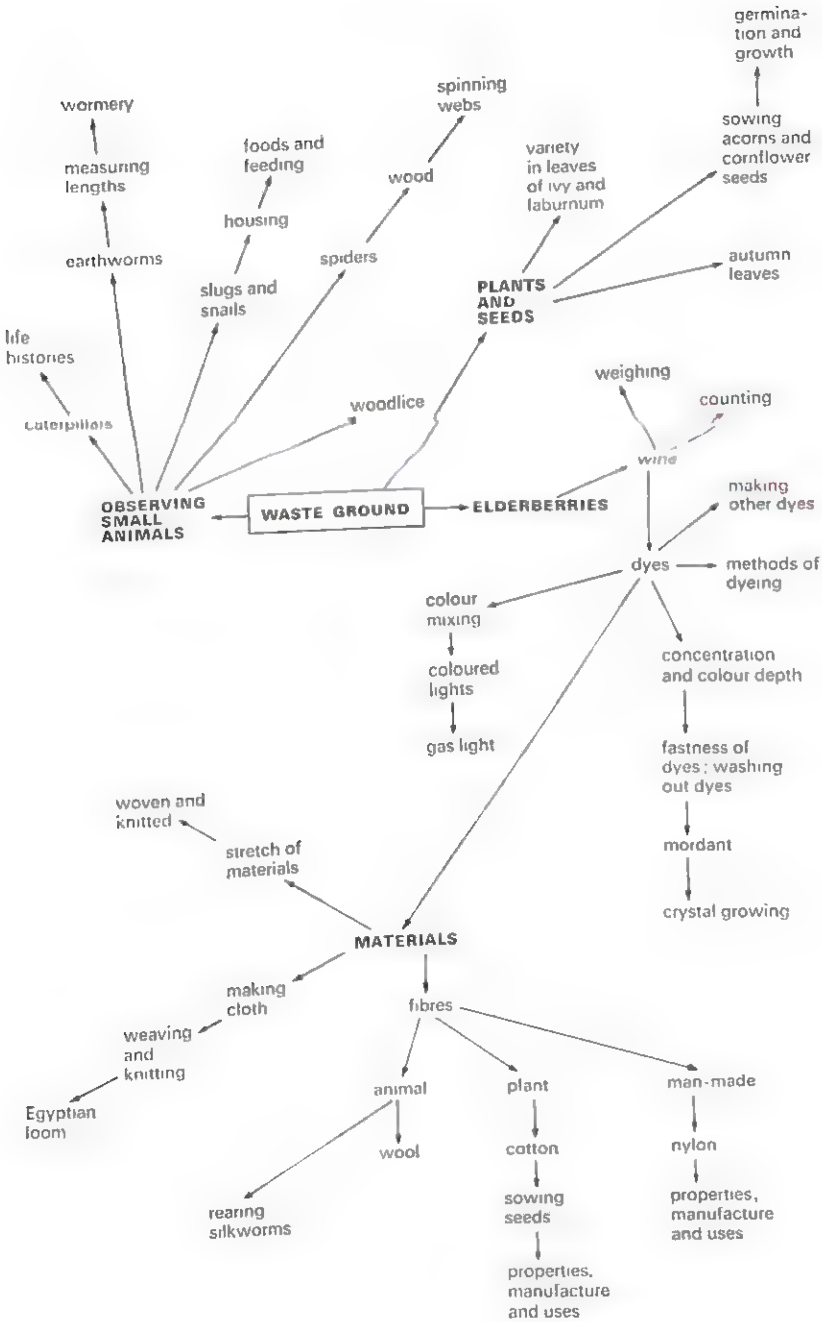
Joan wanted to print some cloth and was given a length of plain white cotton. The other children in her group watched her begin and quickly decided that they would like to do the same. Some attractive designs were produced.

Four girls used a microscope to examine threads pulled from different materials. They began to notice differences and similarities and to ask what the threads were made from. At first the teacher had to tell them, 'This is nylon, this is wool,' but after a time they

*Thurstan, V. (1930) The Use of Vegetable Dyes. Revised edition. Dryad.

began to recognize them and realize that they could be grouped as animal, plant, or man-made fibres. They each decided to find out all that they could about one particular fibre. Lea chose nylon, Jean chose cotton, Lynda chose silk, and Kim chose wool. They wrote to manufacturers asking for information about how the fibres were made, and searched through the library to see what could be found there. The teacher brought some silkmoth eggs for Lynda so that she could see the raw silk being made. Jean found some cotton seeds in a cotton sample box and these were sown in the hope that they would grow into cotton plants.

It seemed clear that long before the silk-worms had spun their silk, the children would have moved on to new investigations.


WASTE GROUND
OBSERVING SMALL ANIMALS
caterpillars
life histories
earthworms
measuring lengths
wormery
slugs and snails
housing
foods and feeding
spiders
wood
spinning webs
woodlice
PLANTS AND SEEDS
variety in leaves of ivy and laburnum
sowing acorns and cornflower seeds
germination and growth
autumn leaves
ELDERBERRIES
wine
weighing
counting
dyes
making other dyes
methods of dyeing
colour mixing
coloured lights
gas light
concentration and colour depth
fastness of dyes; washing out dyes
mordant
crystal growing
MATERIALS
stretch of materials
woven and knitted
making cloth
weaving and knitting
Egyptian loom
fibres
animal
wool
rearing silkworms
plant
cotton
sowing seeds
properties, manufacture and uses
man-made
nylon
properties, manufacture and uses

18 Light

Class	**8-9 years. Upper of two streams**
Class number School roll	43 boys and girls 348
Term	Autumn
Building	Dark and depressing. Built in 1905. A grimy island in a sea of tarmac. In spite of this, the atmosphere within the school is lively and pleasant.
Classroom	Cramped. Extra tables are set out in the hall. Several classes overflow into this at the same time. Adequate display space on the walls.
School environment	Built-up area.
Local setting	South-west England. Suburb of large industrial city and port.

Materials and objects connected with light were placed on the science table. These included brightly coloured acetate strips, different kinds of lenses, a microscope, mirrors, prisms, a kaleidoscope, an electric torch, one clear and one pearl electric light bulb, and a wide variety of coloured papers.

Guy Fawkes night started a discussion of the many colours seen in the fireworks. Some children made block graphs showing the favourite fireworks bought, and others wrote firework poems.

The coloured strips of acetate aroused much discussion and excitement. When looking through the green strip, Fiona said, 'I feel like Dorothy in *The Wizard of Oz* entering Emerald City.' Later she wrote a story about this. The children soon realized that by looking through two strips it was possible to make a third colour. One child, who couldn't understand this, was told by another, 'You must hold it up to the light.' Discoveries were made when they looked through three strips at once. Certain combinations of three, they noticed, made everything appear 'black'; all they could see was the 'switched-on' electric light bulb. Rachel observed that the filaments looked 'spiky'. On being asked why only the electric light bulbs could be seen, one child answered, 'because most light is coming from them.' Lynne asked, 'Why is the red fraction board yellow when I look at it through the purple strip?' Other children took this up and examined red objects through the purple strips.

These experiments with the acetate paper aroused interest in mixing colours with paints. Patterns were made with mixed

colours and coloured strips of tissue paper. It was realized that red and purple did not make yellow when paint colours were mixed. Some children compared paint combinations and acetate combinations. One or two children plaited coloured strips of tissue paper, others made 'mosaic' pictures by using varied brightly coloured papers.

The teacher placed a large disc in the classroom. It displayed the colours of the spectrum. The colours were also painted on the wheel of a rotating grindstone so that the effects could be seen of spinning colours quickly. Several children made small discs, colouring the sectors. Some practised hard at home to make hexagons in order to make hexagonal discs. A small group used flashlights and coloured Cellophanes to experiment with mixing light colours. These were carried out in the dark room.

On looking through prisms it was soon noticed that the colours of the rainbow could be seen on the edges of everything. The children volunteered information as to where these colours could be seen (e.g. oil patches and bubbles). Large and small bubbles were made in the classroom. It was noticed that reflections of the classroom windows could be seen in them.

Later, when looking at the glycerine and soap solution used for bubble making, a discussion arose about skin. Two boys tried to devise an experiment to find out if water has a skin. They filled the sink with water and very carefully pressed a drinking straw on to the surface.

The story of the first rainbow—Noah's Ark—was read from the Bible. The actual measurements given in the Bible were used to make a scale model of the Ark using clay and cardboard. Several children wrote the story of the Ark, while others wrote their own imaginative stories. Many wrote poems about bubbles and rainbows. Two children measured things around the hall in cubits, the Ark measurements being given in cubits. They referred to a textbook to find other units of measurement used at the time.

The children made displays of differently coloured objects and of rough and smooth objects. One or two referred to textbooks to find why some things were rough and others smooth. Several bounced a rubber ball onto different surfaces after being told that light bounced from objects in the same way. Some children took varied coloured pieces of paper into the darkroom and found that bright colours and white reflected most light, while black and dark colours reflected least.

The mirrors were handled frequently and reflections made on the walls and ceiling of the classroom. One child quickly noticed that a mirror which gave an enlarged image bulged outwards, one giving a smaller image bulged inwards, and a mirror giving a true image was flat. Later, the children compared their own highly concave mirror with a slightly concave shaving mirror brought by a visitor. One boy, examining this said, 'This must be a convex mirror because my face looks bigger. Convex means making things look bigger.' Recourse to the dictionary clarified the meaning of the terms convex and concave but did nothing to resolve the mirror problem. The teacher asked how one could tell if a table were flat. 'Hold a ruler on it and if you can see daylight under it, the table is not flat.' The principle was quickly applied to the shaving mirror. Paul held a small straight edge along its surface. 'It curves inwards,' said Margaret. 'That means it must be concave,' replied James. 'But it's not like our highly concave mirror!' exclaimed Paul. As his probing finger approached this mirror, he cried, 'Look! My finger is magnified!' The other children confirmed his observation. Margaret moved her finger up and down to see the sudden change from a magnified erect image to a diminished inverted image. The teacher said, 'I wonder if the shaving mirror can make you look smaller.' In a second Margaret had propped up the shaving mirror on the edge of the table. She backed away from it, staring intently. 'I'm upside down and small!' she exclaimed. Again the other children in the group followed her example and looked into the mirror from a distance.

On another occasion when a different group of children was handling the mirrors, Julie asked if the concave mirror was 'twisting' the light rays. After a further discussion, the children wondered if light hitting an ordinary mirror was travelling 'straight'. With help and suggestions from the teacher the children devised two experiments to see if light travelled in straight lines. Three pieces of card were propped up with books. A flashlight was shone through holes made in the middle points of the cards onto a piece of black paper. A piece of thread was passed along the path of the beam. One child doubted that the light was travelling in a straight line because tiny circles of light appeared on the bench below the holes. He was convinced that light was being bent for this to happen. However, another child in the group thought this was probably a reflection from an electric light bulb, and when the classroom lights were switched off the circles of light disappeared. Using the same three pieces of card, a candle flame was placed at one end and could be seen through the holes. On moving one card slightly sideways the flame could no longer be seen.

Objects were examined through a hand lens and two boys tried to find how much the lens magnified by using rulers. Then they tried to make a microscope by fixing two convex lenses to a ruler with Plasticine. They realized they had to adjust the distances between the lenses and the object in order to get a clear image.

One child said that if an ordinary mirror was placed facing a convex mirror one could see repeated reflections. Another child observed this happening when two ordinary mirrors were held facing each other. Mirrors were held at right angles and observations were made. A small object was held between two facing mirrors and the children tried counting the objects they could see. They realized they could see reflections of reflections. Two children, on looking in a large mirror at the image of their feet, were asked by the teacher if the image was the same distance from the base of the mirror as their real feet. They counted the floor boards and the distance was the same.

The kaleidoscope was a source of interest and it was quickly realized mirrors were used. Several children tried making one. Mirrors were hinged together and one was placed underneath, and coloured pieces of paper were put inside. Richard suggested a piece of tin placed inside might produce a better effect. Eventually one piece of black cardboard and two mirrors gave the desired effect. The 'sameness' in every pattern was noticed and this became a starting point for a study of symmetry. Several children made symmetrical patterns.

Frankie made a periscope at home and one or two other boys tried making one at school.

David had been to a rugby match and noticed that a different ball was used after there had been complaints that players were constantly dropping the ball on account of bad light. A luminous white one was used instead. This initiated much discussion about luminous and non-luminous objects: watches, cats' eyes, traffic lights. The children remembered a poem read previously—*The Dong with a Luminous Nose*. They realized the sun was a luminous object. One child asked, 'Why can we see at night?' Another child suggested, 'By the moon!' On being told the moon was a non-luminous object another member of the class said, 'The moon's light is reflected from the sun.' The class discussed the moon's surface. The following day, Peter, who had looked through binoculars at the moon, said he couldn't really describe what he had seen but could draw it. This he did. One or two children experimented in the darkroom with a flashlight and ball to find how the moon reflected the sun's light. One or two children found out about other lights in the sky; lightning, comets, and stars.

Lynne noticed that the stones inside a fish tank appeared bigger from above than from the side. Objects such as rulers were placed behind the tank and it was realized that the water was bending the light. The teacher suggested an experiment. Water was slowly poured into a dish to make a coin inside

slowly appear. The children enjoyed this and most of them were anxious to do it themselves. It was noticed that the glass block on the science table bent light in the same way.

During the entire period spectra were noticed in various parts of the classroom. Tony was very thrilled when he projected the spectrum behind the curtains of the puppet theatre by holding a prism at a certain angle. Another boy wondered if the spectrum could be obtained from an electric light and found that it could.

A film strip entitled *Colour in Animals* was shown to the class. Many of the children were especially interested in the camouflage pictures and found out more about how colour helps animals, from reference books. Angela told how her family had kept badgers in captivity. In the early hours of the morning, they had scratched on their shed door, trying to come into the light. Another member of the class insisted that badgers preferred the dark and several children found extra information about animals which hunt at night and creatures which live in the dark.

Some insects were found in the playground, mostly under an old P.E. mat. A discussion followed as to why this was. The children made several suggestions:

'Because it's damp.'
'Because they are frightened of children.'
'Because it's dark under the mat.'

Graham and Roger designed an experiment to see who was right. Woodlice and centipedes were placed in a wooden box with a damp cloth in one corner and a piece of card covering another. The animals moved into the dark corner. Graham said this was what he expected since these animals also live under stones. When they covered half the wormery with black paper, the worms moved to the dark side.

When planting bulbs for the school spring flower show the children were curious to know why they were supposed to put the bulbs on the roof underneath sand. One suggestion was that they would grow too quickly in the light. The teacher asked if anyone could suggest how this idea might be tested. Julie said, 'Put some bulbs on the window sill in the light and some more in the darkroom.' Another suggestion was to put bean seeds in both transparent and opaque containers. Some runner beans were planted in cardboard boxes and small windows cut in the sides to see if they would grow towards the light.

From traffic lights as a safety device, other uses of colour as a means of safety were discussed. Colours playing a part in road safety were referred to (cats' eyes, car reflectors, headlights, road lights). Several children heard on television that policemen were to have lights fitted to their helmets. It was found that colour played a large part in ship-to-ship signalling, ship-to-shore signalling, life jackets, buoys, lightships. Much interest was shown in lighthouses. Peter asked, 'Why are they always painted red and white?' Pictures were drawn and painted to find out about the construction of lighthouses, and where they are built. Three boys made a model of a lighthouse, and made a light at the top with wire, battery, and bulb. From this developed an interest in simple circuits. One or two boys went on to make a tapper for sending Morse code messages. They used a piece of wood, an electromagnet, nails, corks, and an Oxo-tin lid. Peter made an electric bell at home. Several children wrote poems about lighthouses and a small group enacted a road safety play. Another group did a play about safety at sea. Some wrote stories about lighthouses.

Shadows were seen on the closed curtain of the puppet theatre. The children worked out how to create shadow puppets. A group wrote a short play and made shadow puppets. Two children experimented with a candle flame and matchbox to find out how shadows vary in length. Another two went out into the yard at various times to draw round their own shadows. The class was brought together for a discussion on the human eye. Afterwards, one or two children shone a light into each other's eyes and could see the pupil getting smaller. One boy timed with a stop-watch how often a certain member of the class blinked. Several children did block

graphs showing eye colouring of the class members.

Several children timed the traffic lights. One or two were puzzled by the results. Frankie pointed out the device in the road responsible for the changing of the lights. As the work came to an end one or two boys were wondering if it was the weight or speed of vehicles that brought about the light changes.

19 Central heating

Class	**9-10 years. Full range of ability**
Class number School roll	36 boys and girls 285
Term	Spring
Building	1902 Well maintained
Classroom	Pleasant and fairly spacious. Windows high in walls. Modern furniture.
School environment	Industrial part of town. Rows of back-to-back houses. A small park next to school.
Local setting	North-east England. Urban area. Heavy engineering, textiles, chemicals.

One cold morning, the teacher started a discussion by asking how the school was heated. All of the children knew that hot water pipes kept the building warm, but only a few could give much more information. Philip knew that there was a boiler to heat the water. Malcolm, who had seen lorry-loads of coke arrive, said that the furnace burned coke.

David P. asked, 'Is the Infants' [a separate building] kept warm from our boiler room?'

'Yes,' said Margaret, 'there's only one boiler room so it must be. Some pipes must go under the yard where we can't see them.'

Ian broke in, 'I should think the Infants' is colder than the Juniors'.' When the teacher asked why, he replied, 'Well, if the pipes go under the yard they'll get cold.'

This led them to discuss which classrooms were the warmest. They decided to take the temperature in each to find out. When they discussed how it was to be done, Margaret pointed out that if one classroom had all of the windows open it would be colder than one that hadn't and suggested the best time would be early in the morning when there was nobody in the classrooms and all of the windows were closed. Eventually they agreed to leave thermometers in the classrooms over the weekend and to read them first thing on Monday morning. The teacher asked Margaret if she could prove that the room was colder when the windows were open and she agreed to try.

When the children returned on the Monday they found that the teacher had set out a quantity of materials and equipment for them to use in their enquiries:

Thermometers of various kinds—alcohol, mercury, dial type.

Spirit burners in trays of sand. (The teacher showed all of the children how to use these properly, and stressed the importance of safety precautions.)

Asbestos mats, wire gauzes, tongs, candles.
Containers—metal cans, beakers, assortment of cups, pans.
Fabrics—wool, cotton, felt for lagging pipes.
Milk straws, spoons, Plasticine, medicine bottles, aluminium foil.
A display of books with sections on heat.

The children were most interested in reading the temperatures in the various rooms, and when they were entered on a large block graph, it showed clearly that the rooms nearest the boiler house were the warmest. Ronald and David H. suspected that the radiators in the corridor, which ran the length of the building, would follow the same pattern. They asked if they could test them. They returned saying, 'The radiator nearest the boiler room is two degrees hotter than the one at this end.'

The children asked if they could visit the boiler room. This was arranged and they went in two groups. The caretaker answered several questions asked by the boys, but the girls seemed less interested and only asked one question. One or two children wrote about the visit and Susan, a slow learner, made a large painting of the boiler. This surprised her teacher who wrote, 'This painting kept Susan's concentrated attention for about twenty minutes, which is unusual for this child whose attention wanders very quickly from one thing to another.' The remainder of the children were so interested in taking temperatures that they eagerly returned to the thermometers and took temperatures at various points throughout the school. The children themselves decided how they would record their findings. They used the materials available in the classroom and tried several methods. Marlene made a block graph, a group of children drew a sketch map of the school and wrote the figures on it, others made neat lists or used columns. For example:

ROOM	TEMPERATURE
Class 1	62
Class 2	64
	etc.

When they had completed their records the teacher displayed them and gathered the whole class to look at them. They noticed that for any single room, on a particular day, the figures given by different groups varied by a few degrees. The teacher asked if anyone could offer an explanation and Yvonne said, 'I expect that's because we take them at different times.' Asked why time of day might make a difference, Philip said, 'Because the pipes get hotter on an afternoon.' Margaret suggested: 'Because we have been in the room longer.' And Colin: 'The sun shines in here on an afternoon.'

They decided to find out whether time of day made any difference to the temperature of their own classroom by taking the temperature at set times each day for a week.

Timothy had taken the temperature of different parts of the classroom and recorded his results on a chart. He showed this to his teacher, saying, 'It's coldest over near the window. I expect that's because it's a bit draughty?' She examined the chart and asked if he had any idea why the centre of the room was so warm even though it was furthest away from the radiators. He suggested that the warm air came up from the pipes and went all round the room. When asked if he could think of a test to see if he was right, he thought for a long time before suggesting that he should put something on the pipes and see if it would move. He was joined by Terence and Malcolm and they tried a small sheet of paper, then a piece of fluff from Malcolm's jersey. The latter moved slightly and spurred them on to try other things including talcum powder, which they brought from home, because it was the lightest thing they could think of. They recorded their results on a large chart.

Susan and Marlene took the temperature of different parts of the canteen dining room which is a separate building. They drew a sketch plan and entered the temperatures on it. The temperature on the side of the dining room which faced an open space was several degrees lower than that on the side which faced a high wall. The teacher asked them if they could explain the difference in tempera-

ture between the two sides and they argued as follows:

MARLENE: Because of the windows.
SUSAN: No, that's not right, because there are the same number on that side.
MARLENE: It's not because of the door, because they are both the same distance from the door.
SUSAN: The walls are just painted-over brick but that's not the reason because that wall is just like that as well.

When they had eliminated their first explanations and could not think of any more, the teacher advised them to go back and look for differences which might explain it. When they returned, Susan said, 'I think it's because that wall outside shelters this side. It keeps the cold winds out.'

The teacher offered them a candle and piece of card and asked if they could devise a test to see if a wall could keep a cold wind out. They lit the candle, held the card in front of it, and blew. The candle remained alight. When they removed the card, it blew out.

Marlene held her handkerchief up and blew through it. The flame flickered. She commented, 'The hankie must let a bit of air go through 'cause the candle moved.' They decided to try other materials to find out which would let air through and which would not. They worked eagerly and soon had a long list of materials. Next to each they wrote 'went out', 'flickered', or 'didn't move'. Marlene said, 'Wool lets air go through and I thought we wore wool in winter to keep us warm.'

Carole who was listening said, 'Wool does make you warm.' The teacher discussed the point with them and together they devised a way of testing Carole's statement. They put some cold water in a metal can, took the temperature, wrapped the can in wool, and set it aside for ten minutes. Carole was very surprised when she took the temperature again at the end of this period and found it unchanged. She said, 'Well, wool doesn't make you get warm.' Susan commented, 'But if you're warm already it keeps you warm. It

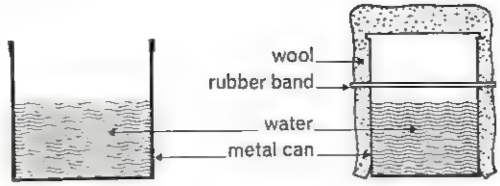


FIG. 29. Apparatus to test insulating properties of wool.

stops you getting cold.' Again the teacher asked if they could test the explanation and Denise suggested, 'If we get some hot water and put it in a tin and cover it with wool, the water won't get cold.' This was tried and the teacher discussed the results with them. The water still cooled down, the wool didn't stop it from getting cold. What then, did it do? Gradually they got round to the idea that it affected the rate of cooling, that the water would cool more slowly if the can were wrapped in wool than if it were not. They used two identical metal cans to test this idea. Their apparatus is shown in figure 29. In each they put a measured quantity of hot water. They covered one with wool and took the temperature of each at regular intervals. The uncovered can cooled faster.

Following this experiment they went on to test other fabrics to see how they compared with wool. Three more girls joined the group and the six worked together for the rest of the term. They wrote to a local textile manufacturer for information about wool and received samples and booklets. In one of the booklets they found a reference to the removal of lanolin from raw wool during the washing process. This interested them. They washed some raw wool in the hopes of obtaining some, but they saw no signs of lanolin in the water. Next they tried bleaching wool and also twisting it into threads by hand. At this point, the teacher provided spindles and showed them how to use one, but they found it difficult to prevent the wool from breaking and never quite mastered it. Carole, who was examining cloth samples, asked why some

were 'painted' only on one side. The teacher explained how it was done and they experimented with potato prints.

During a week end Denise and Janet wrote about the ways in which their homes were heated. They showed their work to their teacher on the Monday morning. Denise borrowed a thermometer to find out which part of her living room was warmest. After playtime, on the same day, Janet returned to the classroom and put her gloved hands on the pipes. She turned to the teacher and said, 'It doesn't get so hot when you wear gloves.' The teacher asked why and she said that the gloves must stop the warmth from getting to her hands, and immediately asked if she could try other things to see if they were the same. Helped by Denise and Lynn G., she tried an assortment of materials and kept a note of the results on a piece of paper. The teacher suggested that they should make a large wall chart to show others what they had found. They set to work enthusiastically and, at Denise's suggestion, stuck a piece of each kind of material on the chart and wrote their findings alongside.

Having completed this chart they decided to make another entitled 'Heating our Houses'. They discussed their plans with the teacher, explaining that they would stick on the drawings they had made of the heaters at home. The teacher suggested that they might also cut pictures out of magazines and watched with interest as they started work. They planned out the chart carefully and got Timothy to help them to draw straight lines. He then did the printing in pencil ('in case we make mistakes') and Denise, after checking it, went over it in ink. Finally, pictures of gas heaters which the girls had collected from the gas showrooms, and of electric and paraffin heaters cut from magazines, and the drawings, were stuck on.

The sight of another group writing to a textile manufacturer prompted them to write a number of letters asking for information about gas, oil, coal, and electricity. Later they wrote a booklet about each of these. Timothy began to make a large model of a coal mine and the rest of the children became so interested that it developed into a class activity. It was based on pictures and diagrams in the pamphlets which he had received in response to his letters. Timothy made the cage and winding gear which was powered by a battery-driven motor.

While their interest was high, the teacher told the whole class about work in a modern coal mine, illustrating her talk with pictures, and there was a lively discussion. Several children wrote about coal mining and put their work into a class book which was placed beside the model.

Five boys asked the teacher to explain how an alcohol thermometer worked. She got them to put forward their own ideas and helped them to test these by making simple thermometers using medicine bottles filled with coloured water (figure 30).

They stood them in warm places (on radiators, in hot water) to see how high the water would rise in the tube. Ronald noticed that when one had been standing, unused, for a day or two, the paint which had been used to colour the water settled to the bottom. He asked whether it was possible to use other liquids which were already coloured and sug-

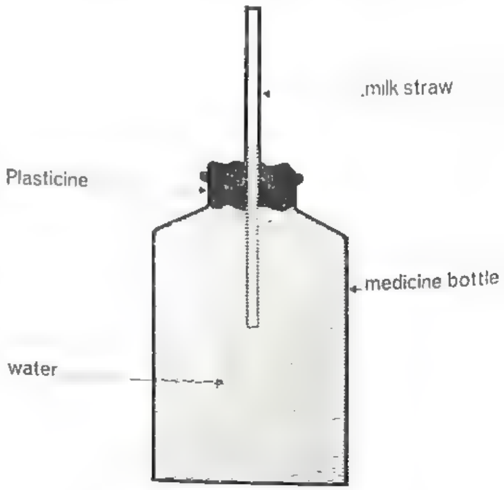


FIG. 30. Water thermometer.

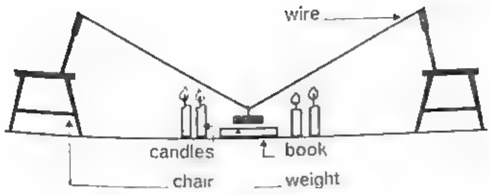


FIG. 31. How the class tested the expansion of metals with heat.

gested blue paraffin. David H., another member of the group, wanted to try methylated spirits which he had seen in the spirit burners. The teacher warned them of the danger of using these highly inflammable liquids but allowed them to try them under her personal supervision. They took safety precautions, ensuring that there were no naked flames in the room. They tested them in hot water and found that although both worked, the methylated spirits expanded most. Ronald commented, 'Methylated spirits must get bigger than water or paraffin', and in the discussion which followed it was clear that this group understood that liquids expand on heating and some expand more than others.

The teacher asked if they could use the same apparatus to find out if air expanded when it was heated. They emptied out the liquid, put the tip of the milk straw into a bowl of water, and warmed the bottle with their hands. Bubbles issued from the straw. Malcolm explained this, saying, 'The air is getting bigger and pushing out'. They speculated about the amount of air which was pushed out and tried to get some idea using an experiment which the teacher found in a book. It entailed fitting a balloon over the neck of a medicine bottle then warming the bottle. The boys tried warming the bottle with their hands but this did not affect the balloon so they put it on the hottest radiator in the corridor and the balloon filled with air. They found this fascinating and repeated it many times. The results showed that there was a relationship between the temperature and the amount of expansion.

While they were still happily repeating the experiment, the teacher said, 'You've found out that some liquids and air expand when they are heated. Do you think you could find out if anything else does?' Nothing more was said for over a week, then Barry asked, 'May we do this experiment?' pointing to a picture in one of the books which was on display. It showed a length of wire stretched between two chairs. There was a weight attached to the centre and a number of candles were used to heat the wire. This apparatus is shown in figure 31.

The boys set up the experiment and David H. reported to the teacher, 'It works, the candles make the wire bigger and the scissors [used as a weight] touch the book.' The teacher watched them repeat it but the gap [illegible] between the book and the scissors was too great and the scissors did not touch it. She suggested raising the books so that the gap was very small when the wire was cold. This was done. When the wire was heated the scissors touched the top book. Had David H.'s first statement resulted from his 'seeing' something which the book had led him to expect? The teacher decided not to tackle him about it.

David P.'s and Stephen's investigations arose from watching Carole's group trying to find out if a can wrapped in wool kept water warm longer than an uncovered one. First they tried to find out if a can with a label on it kept water warmer than one without a label. Then they compared six cans chosen from a large collection which the children had brought. They chose cans of different sizes and put an equal quantity of hot water into each. This was measured by making a mark on one can and filling each from it. They took the temperature of the water in each at regular intervals to see which cooled fastest. Four more boys joined in and the group remained together for the rest of the term. At the end of the experiment they wrote, 'If you put the same amount of water in all the tins the biggest tin gets coolest the quickest.'

Before the teacher could discuss with them the precise meaning of 'biggest', whether it referred to height, diameter, or capacity, they embarked on a new experiment. This time

they got a number of containers made from different materials such as plastic, glass, and metal, regardless of size. They put the same amount of hot water in each and found that although the largest cooled first, the others didn't follow the expected pattern. Some small containers cooled faster than others of medium size. A number of possible explanations occurred to them. Some of the lids didn't fit properly; some had labels and others hadn't. Perhaps the material from which the containers were made affected the cooling rate. They decided to gather more precise evidence by using containers all of the same dimensions and all with tight lids, but made of different materials. But they found it difficult to standardize their equipment in this way and no definite conclusions could be reached.

Another group was given some old insulated school meals containers. The children saw them and Ian believed that they were 'made of two layers of tin with something like cloth in between'. When the teacher asked why, he explained that cloth stopped heat from escaping. She asked him if he could prove that this was true. They put a small can inside a large one and stuffed cloth between the two. Another small can stood nearby, not lagged. They put hot water in both and found that the insulated can retained the heat longer. Their experiment is shown in figure 32.

Elizabeth's curiosity was aroused when she watched some girls spinning raw wool. She wondered if wool would keep a sheep really warm. She tested raw wool by filling two similar cans with hot water, covering one with the wool and leaving the other bare, then taking the temperatures every five minutes. She was joined by Susan P., Colin, and

FIG. 32. The children tested the insulating properties of cloth.

Barbara. The following week they tested a fur cape, which Elizabeth had brought from home, to see if fur kept animals warmer than wool. Later, Susan brought some feathers to test. During a class discussion, the teacher got them to tell the other children about their tests, then mentioned that birds were able to fluff out their feathers in cold weather to keep warm. Timothy said, 'The air stops their bodies' heat from getting out'.

The insulating property of still air was also touched on in an experiment which Susan C. and Marlene performed. They filled two cups with hot water and put one in a paper bag. After an hour the one in the bag was warmer than the other. Susan said, 'Paper must stop the heat coming out.'

David P. disagreed: 'I don't think it does, because if you put paper on the pipes and feel it, it gets too hot.'
The teacher asked the whole class for opinions about this and Terence said, 'I know, the air in the bag keeps the water warm.'

A number of children noticed the upward movement of heated air. Christine and Lynn V put a damp cloth on the radiator to dry. After a time Lynn said, 'Look! Steam is coming off the cloth and it's going upwards. That must be because hot air rises.'

Presently, Hazel and Pat heated a tin containing water over a candle to see if it was possible to boil water with a candle. As they watched, Pat said, 'Look! The smoke goes upwards.'

Hazel replied, 'Well the hot air pushed it upwards I expect.' All these comments gave rise to group and class discussions.

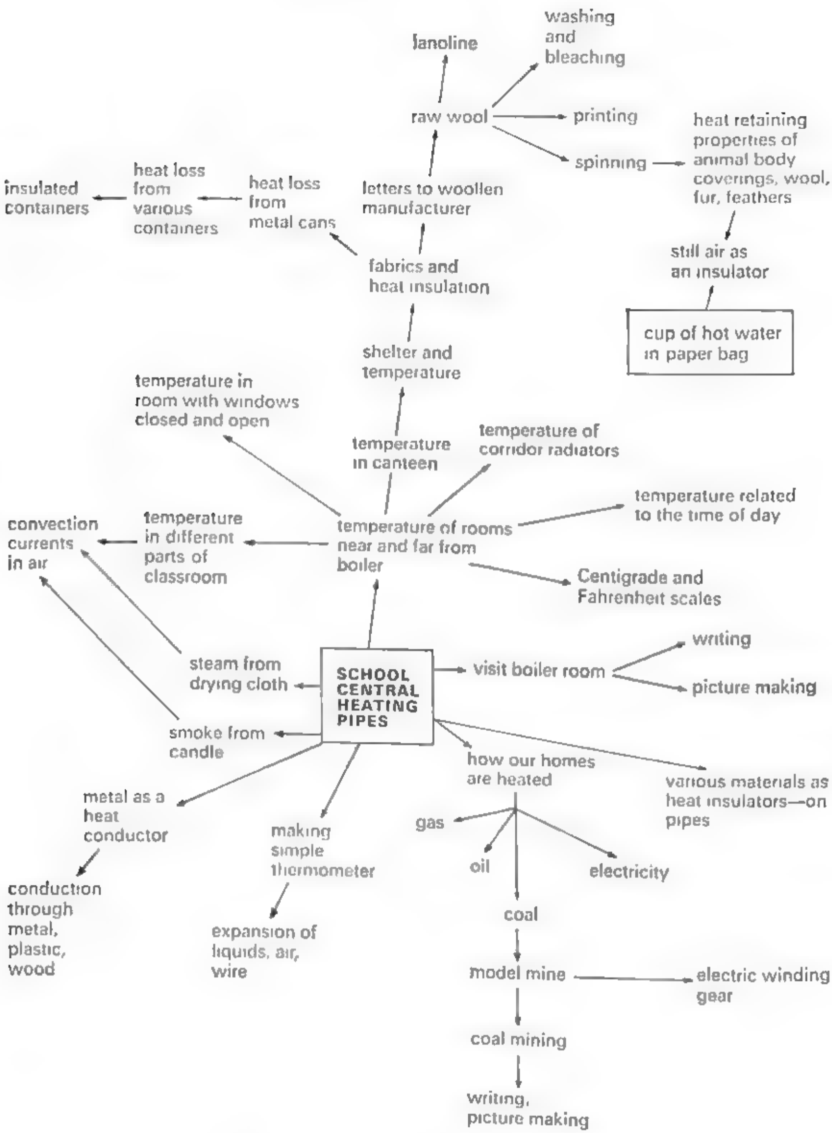
Hazel and Pat soon became more interested in the fact that the tin was heating up rapidly than in the possibility of boiling water. They decided that, 'heat must travel through tin.' Hazel told the teacher that they wanted 'to see if heat travels through things' She asked what they had in mind but they hadn't made any plans, so they went off to think about it At first they suggested, 'We could put some things in hot water and see if they got hot.' The teacher asked what they would use. They suggested a knife, fork, and spoon. The

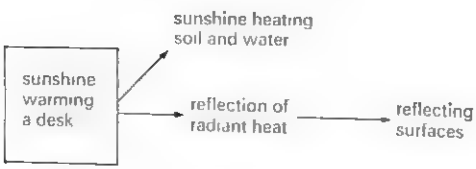
teacher asked what was the difference between these. They realized that they were all made of metal and went off to think again. Two days later they showed the teacher a wooden spoon, a metal spoon, and a plastic spoon which they had brought from home. These were then tested in hot water. They found that heat travelled quickly through the metal spoon but didn't appear to pass very far through the wood or plastic ones.

Although the children were using Fahrenheit and Centigrade thermometers and also thermometers mounted on wooden bases marked in both scales, it was nearly two weeks before Graham asked what the 'C' stood for. Tommy informed him, 'It stands for Centigrade and the "F" stands for Fahrenheit like on the weather forecast.' No one could offer any further information although Tommy guessed that the two scales might be related like feet and inches, so many Centigrades making a Fahrenheit. The teacher therefore told the whole class about the origin of the scales and they listened intently.

One sunny day Susan said aloud, 'My desk is getting warm where the sun is shining on it.' The rest of the children were immediately interested. A discussion started about sun and shade. Lynn V. put thermometers about a foot apart on her desk, one in the sun and one in the shade. There was a difference of several degrees. This established the fact that the sun warms things.

The teacher asked whether they thought the sun would warm the sea as well as land, and which would heat up faster. Hazel suggested putting some soil and some water in the sun to find out. While Hazel and David S. were carrying out the experiment, Malcolm noticed that a tin lid was reflecting the sun's rays onto the wall. Yvonne said, 'I wonder if it is warmer because it is not in the shade any more.' The other children thought it would be warmer and this led to further experiments. Lynn V., Philip, and David took a shiny tin to the boiler room to see if they could reflect the heat from the furnace and found that they could raise the temperature by four degrees. Malcolm, Barry, and Colin tried many things to find out which would reflect the sun's rays and concluded that shiny things like glass and mirrors were necessary.


lanoline
washing and bleaching
raw wool
printing
spinning
heat retaining properties of animal body coverings, wool, fur, feathers
still air as an insulator
cup of hot water in paper bag
insulated containers
heat loss from various containers
heat loss from metal cans
letters to woollen manufacturer
fabrics and heat insulation
shelter and temperature
temperature in room with windows closed and open
temperature in canteen
temperature of corridor radiators
temperature related to the time of day
convection currents in air
temperature in different parts of classroom
temperature of rooms near and far from boiler
Centigrade and Fahrenheit scales
steam from drying cloth
SCHOOL CENTRAL HEATING PIPES
visit boiler room
writing
picture making
smoke from candle
how our homes are heated
various materials as heat insulators—on pipes
metal as a heat conductor
making simple thermometer
gas
oil
electricity
coal
conduction through metal, plastic, wood
expansion of liquids, air, wire
model mine
electric winding gear
coal mining
writing, picture making


sunshine heating soil and water
sunshine warming a desk
reflection of radiant heat
reflecting surfaces

20 Leaves

Class	**9-10 years. Upper stream in two-stream school; nevertheless, range of ability is wide**
Class number	42 boys and girls
School roll	523
Term	Autumn and spring
Building	A one-storey brick building erected in 1934
Classroom	Cramped conditions for this large class and there is little space for free movement. One wall is used for display. Storage space is completely inadequate.
School environment	Large paved playgrounds, bordered on the roadside with grass verge and shrubs. Classrooms arranged around two pleasant grassed quadrangles with flower borders. Swimming bath as a separate block.
Local setting	North-west England. In the midst of a housing estate about six miles from the centre of a large industrial city, housing a population engaged in a great variety of occupations.

Autumn term

In the first art lesson of the term the children painted 'fantastic' leaves. Real leaves were brought in by the children who seemed surprised at the great variation in shape. They decided it was much more interesting to paint proper leaves than made-up ones and a study of leaves began in earnest.

Some children made collections of leaves for beauty of colour and shape; others studied the details of structure of particular leaves, making lists of the words they used to describe texture, margins, colour, and veins. More paintings were done and the children tried matching original colours. Leaf prints and plaster casts were made by some of them and in trying to identify their specimens they asked each other or consulted books from the library. One group of six boys spent hours in a wood at the weekend. Two boys sat on logs with books while the others collected leaves for identification. Fruits, seeds, and branches were brought in by the children and the classroom began to look like a wood!

A visit to look at the trees in the grounds of a nearby private estate was arranged. The children were very excited and obviously enjoyed being out of doors. They decided to join up with friends in small groups to study particular trees. Height and age seemed to be the first queries. Some guesses and estimations were made. These were checked

later. Leaves, twigs, and old pieces of bark were taken back to school. Oak apples and willow bean galls had been found by the groups studying these trees. They aroused interest. All available books were consulted for information. Bernard spent over an hour on his own in a field, looking for oak apples with 'no holes in them.' He found five. He opened one and discovered 'a kind of white grub that goes long and short like a caterpillar.' The rest he put in a jar with a perforated lid 'to find out what the grub turns into.' He looked at the grub under the microscope and recorded his discoveries.

The children became interested in the only tree in the school grounds—a poplar. In an English lesson they sat under it, listening, and watching the movements of the leaves. They tried to think of just the right words to describe them. In an art lesson some of them made charcoal sketches of the outline. Comments overheard were: 'It leans over to the left'; 'The branches on the left are larger'; 'Must be the wind'. The class listened to a junior science broadcast about wind (the teacher's comment being 'a good broadcast but far too much in it'). During the next few days the children made and brought to school all kinds of anemometers and wind vanes, all ingenious in design. These were tried out in the playground and their performance appraised. 'It turned round four times in three minutes.' 'Mine turned twelve times in ten minutes.' The need for consistent timing was soon appreciated. Two girls took readings twice daily for a month. They used a stop-clock and graphed their results.

A second visit to the estate was made. The children were left free to study anything which interested them. Some chose a 'new' tree, while others found their way to the 'old' tree to discover more about it. There was a noticeable change in their attitude—they were less excited, more businesslike; they worked together on self-chosen jobs. More information was obtained than on the first visit.

They asked questions the whole time of each other and of the teacher when she was near. 'Finds' were put in plastic bags, if they weren't too big! Roy had found a large fungus, another boy was carrying a rotten log: 'What was the white stuff under the bark?' Clarke had a large stone full of holes: 'What had made them?' The teacher's heart sank when she thought of the not very large classroom and forty-two children, each needing space to examine their 'finds'. The next day every available inch of space was in use. A cry of dismay came from Roy when he discovered that his prize fungus had gone 'all soggy'. General conversation sprang up: 'They die quickly',—'How can we keep them?' The children decided to set up a fungus terrarium in an old sink in the quadrangle.

Interest in fungi captured the whole class and lasted for about two weeks. The children brought in specimens 'from our fence', 'from the rotten part of our garage', or 'from the woods', and books were in great demand for identification. Some children selected interesting clumps or pieces of fungus, and painted them, often in the dinner hours. You can see an example in plate 7. The teacher was amazed at how careful their observations were.

The microscope came into its own, and pieces of gills were examined and spores seen. Roy stated, 'Mushrooms have sixteen thousand million spores—I read it when I was trying to find out about my fungus. I think it is true, too!' Mark worked out a new technique for making spore prints, using sticky paper. To quote his teacher:

> 'When Mark came into the class he wrote a composition in which he stated bluntly that he did not like school. In this work he has developed beyond belief. He has experimented at home, spent weekends looking for things, and his research on fungi is remarkable.'

A great deal of experimental work on moulds was carried out at home and at school, by individuals and groups, and results were compared. Experiments were devised to find out which things produced the most exciting moulds, and what conditions were best for their growth.

The teacher commented that no story books were being borrowed from the library, but only books on things the children wanted to find out about—rocks, trees, and fungi.

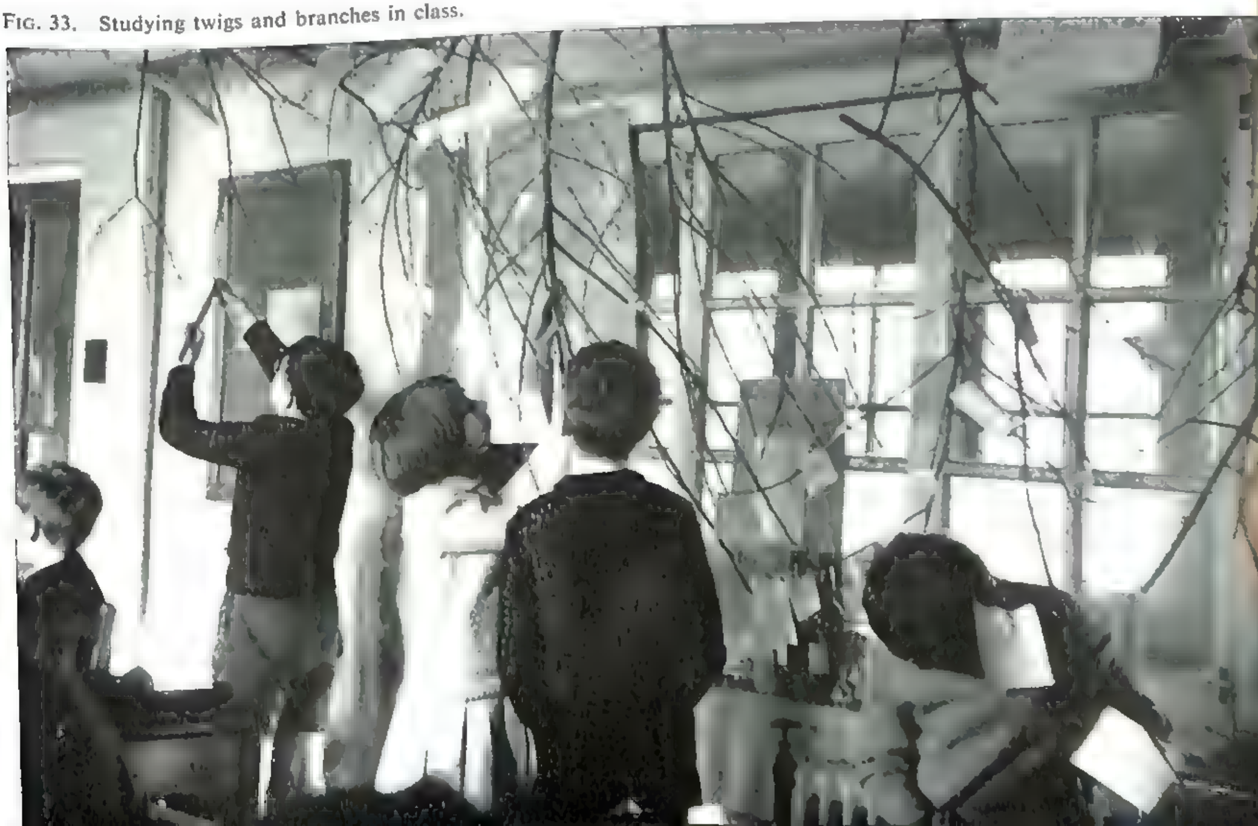
> 'The children are now taking over, and this is a difficult stage for the teacher. For ages we have been used to being in charge. I have never found difficulty in giving children freedom, but I do tend to direct and suggest. Now I find myself lagging behind them; they are so busy and obsessed that I am only necessary as a provider of tools and materials. My role has definitely changed, and not holding the centre of the stage is something I shall have to accept, *but* they still need and demand my interest in what they are doing—which is not easy with a class of forty-two.'

The interest in trees revived when logs and pieces of wood were brought in. One girl had asked for a thick branch from men who were cutting down trees along the road. The caretaker cut it into logs, and much sand-papering was done until the age rings could be counted. Another girl arrived one morning with a branch taller than she was, from a tree her father had been pruning. The question was where to put it. In desperation, the teacher hung it from a pipe running below the ceiling along one side of the room. Branches from other trees were obtained and hung up, and the result can be seen in figure 33. Another surge of interest swept the class. There were detailed studies and drawings of twigs, and much measuring to find out how much the different branches had grown last year.

The children attached pieces of paper and wrote on them the relevant measurements, checking each other's results. Bernard announced: 'This one has grown seven-tenths of an inch.' 'Rubbish,' said Douglas. 'Get the lens, that's just a scar. You must look for more than one scar: they run round the whole twig.' 'Let me see,' said Bernard. 'You're right, it's three and two-tenths of an inch.'

A graph was made of the final findings, after much discussion about an appropriate scale.

FIG. 33. Studying twigs and branches in class.



IAN: Shall we have one block or two to the inch?

CHRISTOPHER: We'll never get the poplar on. It's grown twenty-five inches.

BRUCE: We'll join the paper.

IAN: We'll use one block to the inch and these [small squares] will have to represent two-tenths of an inch.

In talking about the results, a query arose as to which were the commonest trees in the area. The children decided that during the holidays they would identify and count the trees in the roads where they lived.

Spring term

During the Christmas holidays all but a few of the children went round identifying and recording the trees along the roads in which they lived. When they came back to school they began discussing their findings. The general enthusiasm and the fear of being left out of things encouraged the few who had not done anything to collect information. In a short time the whole class was involved. Questions such as 'Where do you live?' and 'How many beeches in your road?' led some of the children to describe where they lived and to give directions for getting there. They discussed precise uses of words with the teacher and with each other. Mark drew a plan to show where he lived. Others followed his example. The need for accuracy was emphasized by the teacher and the children paced out the roads and worked out a scale to fit the particular size of paper they had chosen.

This sparked off an interest in scale drawing. They measured the classroom and corridors and checked compass directions. The teacher wrote, 'Quite a lot of real mathematical thinking is going on; the children are discussing freely and the classroom is full of bits of paper covered with figures. Tremendous difference in ability shown here—the girls love the work but the boys are leading them. The boys also seem to have a natural sense of direction; the girls are much slower.'

At this point the teacher produced a map of the area. The roads covered by the children's tree survey were located, and ways of presenting their findings were discussed. In the end they decided to make a large bar graph. Scale was discussed, the size of paper required was estimated, and a long strip of graph paper was pinned along the top frame of the blackboard. The children experienced some of the difficulties involved in collecting and sorting data from a large number of people, but they gained much satisfaction from the graph when they had completed it.

Man's use of wood seemed to be a natural development of the work on trees. A visit to the docks to see the unloading of timber was arranged for January 21st. In spite of a bitterly cold day the children were keenly interested in all they saw. They asked questions continuously, and made jottings in their notebooks of things that interested them. The official guide was quick to respond to the children's interest; forgetting his 'set pieces', he allowed himself to be 'guided' by the children's questions.

Back in the classroom groups formed according to common interests:

1 Floating and 'dead weight'. (Billy had found out that a collier of 970 tons can carry a cargo of over a thousand tons. 'Why doesn't it sink?' he asked.)

2 Freezing and thawing. Some of the children were interested in the design of the prow of the Russian ship which had passed through ice on its journey.

3 Timber in Canada and Russia. The group considered kinds and uses of imported wood; slow and quick growing trees; hard and soft wood; method of loading. 'Why don't you carry logs?' Ian had asked a Russian sailor.

Other interests centred around:

4 The docks themselves.

5 The machines used.

6 The ships.

7 Coal (which was exported).

8 Cubic capacity in relation to loading cargoes of coal and timber; this concerned only one boy.

The teacher commented:

> 'The children have thrown themselves into this with zest. Even the school examinations did not stop them. They stopped *me*, however, and I was not able to provide the materials necessary for them to develop investigations along scientific lines. *But* they began to read and to spend all their spare time in the library. Now, for some children this would not be important, but it is here. They are not dull children. They have a quick intelligent interest in all they do, but, in most cases, the home background is poor and no real interest is taken in the children. Material comforts are provided but there is no time for communication. There are a television, refrigerator, washing machine and modern cooker, but *no books*. I am torn now between introducing material for experimenting and letting them enjoy this new experience of *finding out from books*.'

While the teacher was involved in organizing the examinations, the groups were more or less thrown on their own resources. They collected a considerable amount of information, gleaned from sources outside the school library. The children concerned (group three) wrote to the Canadian and Russian embassies for information about lumbering. Those interested in ships (group six) turned to history and traced the developments in design. One boy obtained some authentic loading charts, studied them with great concentration, and later explained them to a group of interested children. The 'dock group' became involved in making a big colourful frieze which covered the whole of the back wall of the classroom.

About this time a Scout group lent the children a varied collection of pulleys, ropes, and poles. This material was directly relevant to the work of the group interested in machines. In no time at all they had slung ropes over the high pipe near the ceiling (figure 34) and, to the teacher's horror, they began to haul each other up. They experimented with single and double pulleys and Christopher found that a double pulley halved the effort which had to be made. A 'cable car' was constructed and sent from one side of the quadrangle to the other. In the face of this exciting work, interest in the books began

FIG. 34. Studying pulleys.

to fade. At playtime and lunchtime quite half the class was out in the quadrangle and the other half was in the classroom working with the pulleys. The original groups became fluid and the main interest centred around simple mechanics.

An old sink, on the far side of the quadrangle, was needed to make a home for frog's spawn. Could they move it? Finding out how to do it became part of history when Ian found his teacher to tell her that he was sure that the Egyptians laid down some sort of a track first, because it made it so much easier (the caretaker had given the children some long poles). See figure 35.

The teacher collected more material in the quadrangle to give the children experience of levers (some P.E. apparatus was borrowed from the hall). The children spent an afternoon experimenting freely moving from one thing to another at will. Some kept in groups, while others worked in twos or independently. The teacher noted: 'But all were deeply engrossed. I cannot overstress this absorption —we must see it to believe it. It can be seen on the faces of five-year-olds watching a tank of fish, or a rabbit. It disappears to a great extent in the junior school and is rare in the secondary school.'

Mobiles were an interesting development from the work on levers. Ten children became involved in designing them and they ranged from simple ones to some with complicated systems of balance. (The mobiles were suspended from the same pipe that had held the tree branches and the pulley ropes!)

The provision of balsa wood and small wheels and pulleys produced a spate of model cranes, docks, etc. Both girls and boys made them. Some more elaborate Meccano models were brought from home.

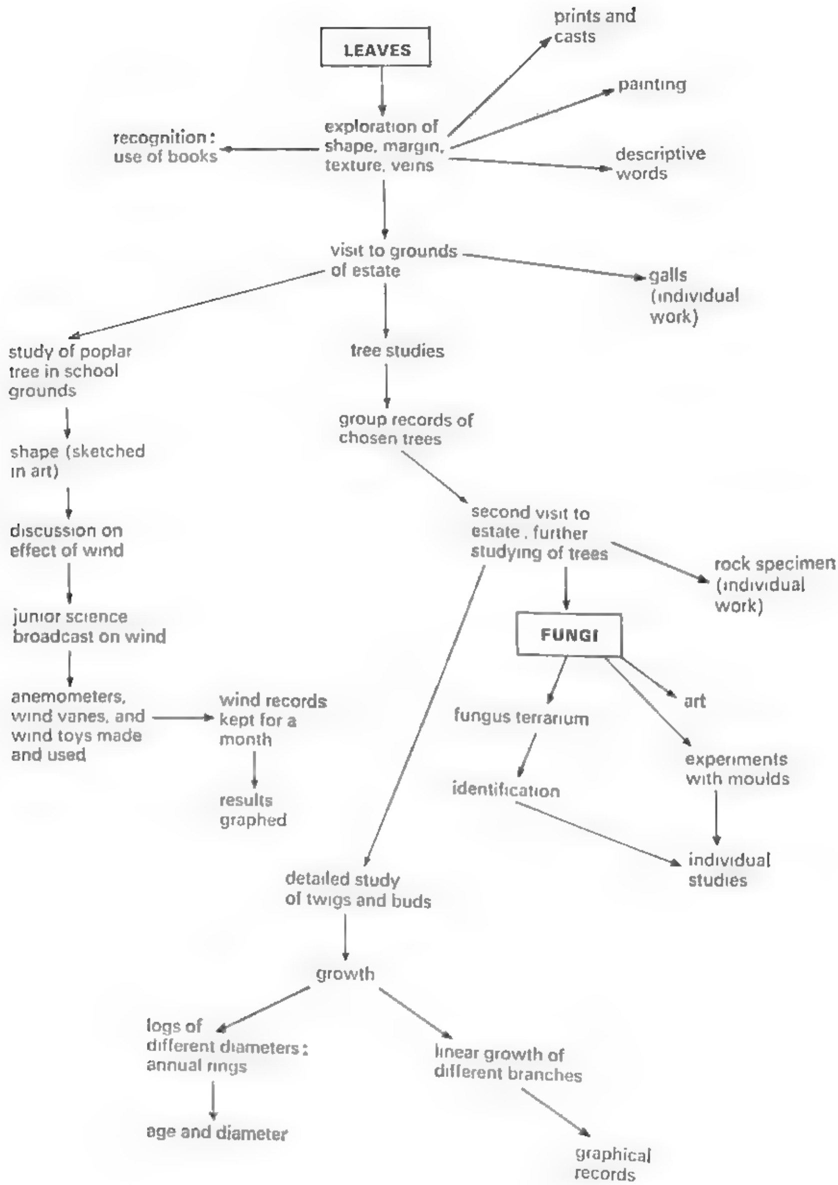
The teacher summed up:

'I feel we have spent a very worthwhile term. The interest that is developing now in the frog's spawn may lead into next term's work. Yesterday I was given a frog; to-day I find myself with a huge toad and

FIG. 35. Ian's idea for moving the heavy sink.

two newts! At the beginning of next term I hope to go out with the children again to see "their own trees" coming into leaf and then on to the pond for a fresh starting point.

'This work needs more teachers, not less. Some people imagine that if a child is discovering he can wander into a mass of apparatus and "discover". Children do not discover in this way—they need the stimulation of discussion, they need to communicate and to share exciting moments—and I find that I need to be in four places at once. Actually they do not *now* really expect me to answer their questions—because they know I usually ask three for the one they asked. But they do need me there.'


LEAVES
prints and casts
painting
exploration of shape, margin, texture, veins
recognition: use of books
descriptive words
visit to grounds of estate
galls (individual work)
study of poplar tree in school grounds
tree studies
group records of chosen trees
shape (sketched in art)
discussion on effect of wind
second visit to estate, further studying of trees
rock specimen (individual work)
junior science broadcast on wind
FUNGI
anemometers, wind vanes, and wind toys made and used
wind records kept for a month
art
fungus terrarium
experiments with moulds
identification
results graphed
individual studies
detailed study of twigs and buds
growth
logs of different diameters: annual rings
linear growth of different branches
age and diameter
graphical records

21 *A nature trail*

Class	**9-10 years. Full range of ability**
Class number School roll	35 boys and girls 285
Term	Autumn
Building	Built 1902 Well maintained
Classroom	Pleasant and fairly roomy. Windows high in the walls. Modern desks and chairs.
School environment	Set within industrial area of town. Rows of back-to-back houses. Heavy industry nearby. A small park close to the school.
Local settng	North-east England. Urban area with heavy engineering, textiles, chemicals, and light industries.

The children visited a nature trail in the largest of the town parks. They took cyclostyled sheets which indicated the route and drew the children's attention to points of interest. Soon they were examining all kinds of things, both on and off the trail. They saw worm casts on the grass verges and asked, 'Where's the worm in a worm cast?' They found pond snails in an ornamental pool and were fascinated by the way they moved.

Canada geese, ducks, coots, and a moorhen were feeding in the stream. The children spent a long time watching them and making sketches, while the teacher was continually replying to questions:

'How does a duck breathe when it's feeding?'
'How big are the wings of a Canada goose?'
'What do coots eat?'

They found the seeds of sycamore, ash, chestnut, and Turkey oak trees lying on the lawns and paths. Normally they would not have been able to collect any specimens in a park, but they collected a few of these, together with some of the autumn leaves which had fallen. They were mostly interested in animals and were delighted to find that the trail ended at the park aviary where they saw a penguin and a magnificent peacock.

Susan and Denise wanted to write a book about the nature trail. They began it at home and continued in school, filling it with observations and drawings.

Next morning, when the children came into their classroom they found a selection of reference books attractively displayed on one of the tables. Within minutes, a crowd had

gathered round the table. The children were busily searching for pictures of things they had seen on the nature trail. This naturally led to a discussion of all they had seen and done. Those children who wanted to write a booklet about it began at once.

Christine asked for a plant pot and some soil so that she could plant the acorns she had collected and other children, hearing this request, asked if they could do the same. No one knew which way up an acorn should go, so they tried to remember how they were lying when they found them. In the end, they planted acorns in different positions to see what happened. Malcolm had found some amongst stones, while Christine had seen some in the lake. A few were planted under a flat stone and others were dropped into a jar of water. Barbara tried hers with the shell removed. She had already removed it to see what was inside. Susan planted hers under leaves.

Horse chestnut and sycamore seeds were treated in a similar way. The children each made a concertina booklet about germination and growth. They illustrated the booklets with neat sketches.

David painted a large picture of a Canada goose. This appealed to other children, and they drew pictures of ducks, coots, moorhens, and more Canada geese. It seemed a good idea to attract birds to the classroom windows by putting out food for them, but no birds appeared and interest evaporated. Apparently, older children with air guns had made them very wary.

A few children brought tree leaves and fruits to school and wanted to know their names. They matched the leaves to those shown in identification books, but found that this was not always very simple. They felt that it would have been better if they could have had large pictures showing the leaf, twig, bark, flowers, fruit, and shape of the tree, all on one page. Since this had not been done in any of the books which they had seen, they thought they might try to make some identification sheets themselves.

They began by experimenting with drawings of leaves, but soon branched out into spatter and smoke prints, silhouettes, and plaster casts. Bark rubbings were made, using various materials until Ian hit upon the idea of making a rubbing with a candle, then painting over it with a water-colour the same shade as the bark. The children all thought this was by far the most effective method. Fruits and seeds were dried. Twigs were collected and examined. The idea of making identification sheets was forgotten, and the children produced individual booklets of their leaf prints and bark rubbings.

A week after the visit to the nature trail, several children who had decided to write booklets about it had completed them, and were uncertain what to do next. They asked the teacher if there was another nature trail which they could visit. She told them that there was not, but they could blaze a trail through the small park behind the school if they wanted to. They thought this was a splendid idea. Once the trail was made, they could invite other classes to see it. Everyone wanted to join in, even though for some of them, like Denise, it would mean keeping three things going at once: she was already writing a book with Susan and growing tree seeds.

The whole class went to the park for a preliminary investigation. They combed it to see what lived there and held a long discussion to plan the trail. It was agreed that there should be a guide book and a map. Visitors would need a map to follow the route, since the children could not put up signs in a park.

Their next step was to draw up a list of things for inclusion in the guide book. These ranged from trees to spiders, and each child chose what he wanted to study. Thus, groups were formed. Each group would write a chapter for the guide.

The group studying insects and other small creatures was composed chiefly of boys who had enjoyed searching for them under stones, amongst leaves, or in cracks in bark. They used hand lenses to examine their specimens and then made drawings of them. They made cages for them and devised experiments to

see which foods they liked and in what conditions they preferred to live. The children also spent a great deal of time watching their movements.

Barry brought some caterpillars which his father had found on the cabbages in his allotment. They were housed in a cage next to those who had been found in the park. When they pupated, only Barry showed any further interest in them. He examined them daily and made a series of drawings. He expected the mature insects to emerge at any moment. When several weeks had passed and they still had not appeared, he began to seek an explanation.

The children were amazed to see ichneumon larvae emerge from a caterpillar and spin tiny golden cocoons. They wanted to know more about them. The teacher told them the life history of the ichneumon fly. The children decided to keep the cocoons so as to be able to see the flies for themselves.

Susan and Amanda compared a spider with an ant and listed the differences. They put privet twigs in its cage to see if it would spin a web among them, and searched the park to find out what kind of places spiders spin their webs in. When they told the rest of the class about their work, the problem of how a spider avoids sticking to its own web was raised. Books were used to find the answer. They watched spiders feeding on flies, examined webs to find out which threads were sticky and which were not, learned about the control thread, and built up quite a detailed knowledge of the garden spider. They knew, for example, that it has fine hairs on its legs, and they even measured its legs because they looked so long.

A large group of children studied trees and shrubs. They worked in twos and threes on trees of their choice, finding out all they could, and pointing out the things they thought would interest people visiting a nature trail.

Ronald concentrated on holly bushes and thought that the glossy surface of the leaves was probably waterproof coating. He sprinkled water on them and on sycamore leaves to see how they compared. After discussing his findings with the teacher, he made a balance to weigh some leaves and see how much water they lost as they dried.

Denise and Janet wanted to find the width of a tree trunk. No one in their group could help them. They asked the teacher for suggestions. She advised them to find some cylindrical objects in the classroom, measure the distance round them and their diameters, and see how they compared. They used things like tin lids, jam jars, and the waste-paper basket, and recorded their findings in diagrammatic form on large sheets of paper. As the group discussed these the following conversation was recorded:

STEPHEN: Every diameter is a different size.
RONALD: The things with the biggest circumference have the biggest diameters.
YVONNE: The circumference is three times bigger than the diameter.
(*They compared the two on each chart.*)
DAVID: There's a bit left over.

Everyone in the group began to measure the girths and diameters of tree trunks. While they were doing this, Margaret commented: 'We'd be all right if it rained. This tree is like a big umbrella'. Soon they were measuring the spread of the branches and relating this to wind direction.

Carole and Valerie found some toadstools in the park and brought a few back to school to examine. They measured them and drew them, planted them in jars half full of damp peat, and then put them in the school shed and waited to see if they would grow.

While the girls were waiting, one of the acorns which had been planted earlier began to go mouldy, and this started them growing moulds. To see where moulds grow best, they kept bread in different conditions—damp, dry, in dark, in light. At first, the mould did not grow at all because the bread dried out rapidly in the warm classroom, but once the girls covered it with plastic boxes to keep in the moisture it grew well.

The girls were fascinated by its colour and appearance. They used hand lenses to examine

it closely before drawing pictures of it. They weren't sure where it had come from, but thought that it probably grew from seeds of some kind. The problem was solved when they found spores which a toadstool had shed onto the paper on which it was lying. They asked the teacher about them. When she had explained what they were, she told the girls that a mould was a fungus, like the toadstool.

The children found many worm casts and noticed that there were more in some parts of the park than in others. They could not say exactly which part contained most worms. Samples were taken in different areas: flat lawns, sloping grassy areas, under trees, and on paths. At the teacher's suggestion, P.E. hoops were used to give a standard unit, but the children were left to discover for themselves the need to take a number of samples and find the average. As they counted the worm casts, they put them into a plastic box to make sure that none was counted twice. These were taken back to the classroom for further examination.

Most of the children found plugs and brought them to the teacher. She explained what they were and suggested that they should be kept separate.

The children recorded their findings on a large chart and then discussed them. They noticed that there were very few casts on paths, or in front of park seats or in other places where the earth was hard. They thought that there were probably three reasons for this. The soil would be too hard for the worms to tunnel through; it would be rather dry for them, and people might stand on any worms which tunnelled just under the surface of a path. Yvonne pointed out that there were not many casts under trees and this was another dry place because 'the branches shelter the ground from rain'.

On the other hand, the children found most casts on the flat lawns which were damp and soft underfoot. David thought it was the moist conditions which attracted them, pointing out, 'Worms like moisture. They dry up when it's too dry.' A girl added: 'I suppose it's easier to tunnel through wet soil because it's softer.' Worm casts were examined, and the children found that the soil was very fine. They concluded that this was because it had passed through the worm's body.

Plugs were gently teased apart. The children tried to identify the materials from which they were made. They speculated about the kinds of leaves which were used. Were they chosen because they were soft and easy to pull in? Would a worm use holly leaves? Did they just use anything at hand? Why did they pull the leaves by their tips? Was it because a leaf stalk was too big for a worm to get hold of? Wormeries were set up in an attempt to find answers to some of these questions. They were also used to try to find out whether worms preferred wet or dry soil, and whether they preferred to burrow in sand or soil.

Through handling and watching worms, the children learned about the way in which they move. David was the first to discover that they have bristles on the undersides of their bodies. He felt their roughness when he was handling a large worm. The children consulted reference books to find out why the worm has a clitellum. Soon they came across accounts of the life history of an earthworm.

A group of children suddenly announced that they wanted to make a large picture of the east end of the park. During the next fortnight they worked on it in art and craft and science lessons, at playtimes and whenever they had a few minutes to spare. Most of the class contributed to it.

A few days before the end of term, the children put their nature trail guide book together. It contained a number of chapters, telling all that they had found out about each object. They arranged the material in the order in which people would see them as they followed the trail. Maps and an index were included. Finally, at Janet's suggestion, they added a quiz so that anyone who had visited the trail could match his observation against theirs.

22 *A school playing field*

Class	**9-10 years. Full range of ability**
Class number School roll	36 boys and girls (30 girls and 6 boys) 350
Term	Autumn.
Building	Attractive post-war building with modern facilities.
Classroom	Pleasant, light, and airy. Wall blackboards, display space, modern furniture. One electric point. Water.
School environment	Suburban. Large playing field with hedgerow and unmown 'waste' area. Serving a rapidly expanding residential area.
Local setting	North-east England. An urban area with a great variety of industries.

The school playing field seemed to be a promising starting point, for apart from a well kept lawn and gardens, there was a large area of unmown grass, a hedge with leaf litter under it, and a fence with a grassy ditch alongside. The teacher and children searched the grounds to see what they could find.

Few of the children showed any interest in plants and most of them looked for animals. At first they were difficult to find, but once the children began to look under stones and to search carefully amongst the leaf litter, they found them with increasing ease and frequency.

The specimens they collected included worms, slugs, snails, millipedes, centipedes, greenfly, and spiders, but there were also a few plants, including fungi, wild flowers, tree leaves, and a tree seedling which was growing in a soil-filled depression in a brick.

When the children returned to the classroom they remained in the small groups of two or three which had formed out of doors, and these remained steady for most of the term. A door in the classroom opens onto the playing field and the children worked indoors or out, as the need arose.

Ruth and Hilary transferred the millipedes and centipedes they had caught into a small plastic box so that they could watch them closely. They made large drawings of them, and wrote about their appearance and where they were found. The box was too small to make a permanent home for them, so the girls transferred them to a small fish tank. They put soil and turf in it, laid part of a brick at one end for them to crawl under, and covered the top with a sheet of perforated zinc, bending the edges to grip the sides of the tank.

Next morning they found the millipedes and centipedes under the brick but could not decide whether they had gone there because it was damp or because it was dark. This led

to experiments to try to find an answer. The tank was emptied and a fresh layer of dry soil placed in the bottom. The soil was moistened at one end and left dry at the other. Centipedes and millipedes were put in the middle and left to choose which conditions they preferred. This experiment was repeated several times before the girls went on to test the centipedes' preference for darkness or light. They devised two tests. In the first, they put the tank in a dark cupboard for a time and then shone the beam of a torch onto the centipedes and watched their reactions. In the second, they left the tank in a light place but covered one end with black paper and waited to see where the centipedes would settle.

Several children who were attempting to house their creatures asked the teacher what sort of home she thought they should give them. She gathered together all those who were concerned and they discussed the question. They agreed that the homes should resemble the creatures' natural ones as closely as possible. Most of the children could remember where they had found their creatures, but, to record all the information they could, they made a large chart with two columns, one for the animals' names, the other for the places in which they were found. When everyone in the class had filled in the details, they studied the chart and decided which conditions suited each creature best.

The teacher pointed out that if the chart was accurate they ought to be able to use it to predict where each animal could be found. The children tested this. They consulted the chart to see where slugs lived, and then they went into the school grounds and looked for them in the kinds of places mentioned.

On the following day, two girls put stones in different parts of the school grounds to see which animals would crawl under them. They collected further information about the conditions in which animals live, and read about the enemies from which they were hiding.

Once they had housed their animals, the children had to find out what they ate. Some found the information in books, but others preferred to offer their creatures a selection of foods in the hope that one or two would be eaten. The teacher made sure that animals which would not eat the foods offered to them were returned to the places where they had been captured.

Alison, who was watching a spider, asked the question which had been puzzling several children: 'Is it an insect? How do we know?' The children who were interested gathered round and the teacher asked them to look closely at their specimens to see how they differed. They soon told her that beetles, wasps, and butterflies had six legs, spiders had eight, and woodlice, millipedes, and centipedes had more. On the other hand, slugs and worms had none. The teacher explained that the creatures with jointed legs were called arthropods and that *some* arthropods, but not all, were insects. Creatures without jointed legs were set aside and the children concentrated on the arthropods. These were grouped according to the number of legs and the body parts, as shown in figure 36.

From this time onwards, whenever the children found an arthropod, they could tell which one of these groups it belonged to, and this satisfied them. Of course, some children went further. Ruth found that she had caught more than one kind of centipede and searched through a book until she found the names of each of them. She had also thought about the meaning of the word 'centipede' and wondered if hers really had one hundred legs. She counted the legs of one, and found that it had eighteen. Another had so many legs and was so active, that it was difficult to count them, so she estimated one eighth of its length, counted the number of legs on that part of it, and calculated that it had eighty. She could not find a centipede with one hundred legs.

Carol and Judith found a large number of craneflies resting on the east side of a wall. They brought some into the classroom, found out what they were, and made sketches and notes. They found craneflies in the same place for several days but one cold day, when a strong east wind was blowing, Judith announced, 'We can't find any craneflies on the wall

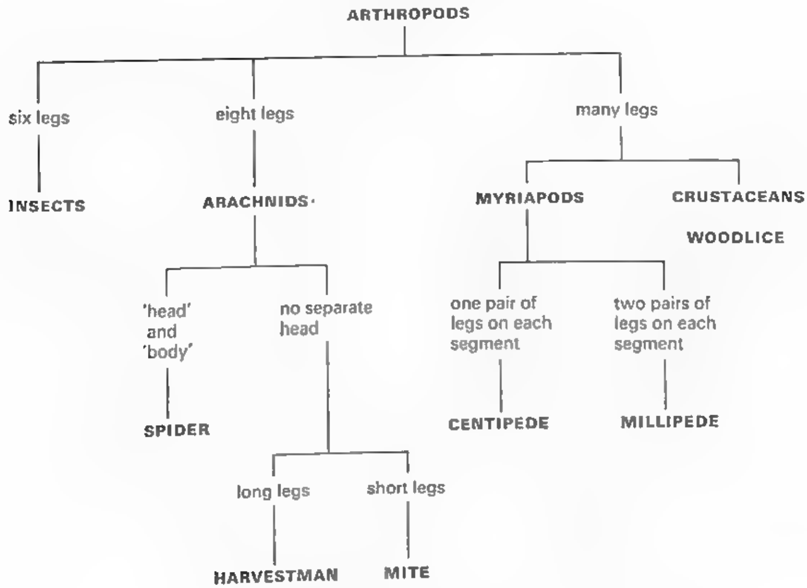


FIG. 36. How the children grouped the arthropods.

today. Do you think something has chased them away or eaten them?'

The teacher suggested that they should look on the wall to see if there were any creatures there which might have eaten them, and that they might also try to find out if anything had changed, compared with other days. They thought that only the weather had changed. Suddenly, Carol said: 'We found some on the other side of the wall. Perhaps they get shelter there.' Judith was not convinced that one side was more sheltered than the other and, remembering the anemometer on the roof of the school, suggested that they make one so that they could measure the force of the wind. When the anemometer was completed they used it to compare the wind strength at each side of the wall over a period of several days. They also took the temperature, arguing that a sheltered place would probably be warmer than one which is exposed. Their findings were related to the number and position of the craneflies which they found each day. It seemed that the craneflies did settle on the sheltered side of the wall, but no definite conclusion was reached.

The children who had become interested in slugs and snails experimented a great deal. They devised ways of finding out whether slugs preferred to live in damp or dry conditions, tested their preferences for light or dark hiding places, found that they moved more easily on soil than sand, and tested their reaction to a beam of light when they had been in a dark place for some time. They found slugs feeding on a variety of plant materials and wondered which were their favourite foods. They tried to find out by offering them a wide choice and seeing which were eaten most. Slugs frequently crawled under a piece of orange peel and the girls wondered if they were attracted by its strong smell. They used an experiment suggested in a book, to see if slugs have a sense of smell. A slug was placed on a flat plate and a thin stream of vinegar poured around it, enclosing it in a horseshoe-shaped ribbon of vinegar. The vinegar was kept in a narrow band and

was far enough from the slug to prevent any danger of it touching the slug's body. The slug moved around, refusing to cross the vinegar, until it came to the break in the circle, when it passed out of the enclosure and moved away towards the edge of the plate.

The girls were surprised to find fourteen different shades of colour amongst the slugs which they had collected. Black slugs were the most common with grey shades next, but they also found slugs which were brown, whitish, straw-coloured, and even one which they described as 'orangey'. They might have gone on to find out whether the different colours marked off different kinds of slugs, or whether they depended on the habitat in which the slugs had lived and were for camouflage, but these paths were ignored. Some slugs' eggs were found under a stone and the girls wanted to watch their development and to find out about their life history.

The children were deeply interested in the small animals which they kept, and the knowledge which they gained through observation and study found expression in a variety of forms. These included language, graphs, charts, models, paintings, and needlework.

FIG. 37. The children embroidered pictures of the animals they were keeping.

It was the children who suggested that they should embroider small animals on the pinafores which they were making. Two are shown in figure 37.

After about five weeks' work, Rosalind and Margaret approached the teacher, saying, 'We don't want to do slugs any more. What shall we do?' They wanted a definite suggestion. The teacher, aware that as winter approached it would become more and more difficult to find small animals in the school grounds, asked whether they had thought about their own homes and how they were built so that they were comfortable places for humans to live in. They thought this was an interesting idea and went off to draw plans of Rosalind's house.

As other children showed increasing interest in what Rosalind and Margaret were doing, the teacher asked the two girls to show their plans to the rest of the class and to tell them something about them. This led to a discussion about the differences between the homes of small animals and those of human beings. Lesley and Rosemary said that they had done some work of their own on the differences between greenflies' homes and ours. They wanted to study materials used in house building. The question of how you begin to build a house cropped up at once and Rosalind described how foundations were laid, explaining that she had watched men doing it on a building site near her home.

The teacher offered to provide materials for anyone who wanted to try mixing cement and asked Lesley if she would like to start her study of building materials right at the foundations. Both Lesley and Rosemary were keen to do this and they began by making several samples of concrete using different proportions of sand, gravel, and cement in each. The mixtures were poured into moulds and, when they had set, were tested to see which was the strongest. Having exhausted their interest in cement and concrete, the girls turned their attention to bricks and tiles. They decided that these materials ought to have a high resistance to the weather and began by putting them in water to see how

this would affect them. In this way they discovered that bricks are porous, and they learned about damp courses and cavity walls. They did not have time to see how these were affected by heat and frost.

Kathryn and Alison collected magazine cuttings and leaflets about ways of heating a home. As they read through them, they frequently came across the terms 'radiant' and 'convector', and decided to find out about different kinds of heating. They began by examining a radiator in the corridor outside the classroom, and used pieces of tissue paper fastened to a stick to trace the air currents around it. Alison noticed that if she held her hand above the radiator the hot air warmed it quickly, but when she held it near the bottom she had to put it much closer to the radiator to feel the warmth, and in this case it was not warm air which heated her hand but direct warmth from the radiator itself.

While Kathryn was reading a book in front of the electric fire at home she noticed that if the book came between her and the fire it cut off the rays of heat. When she held a thermometer at each side of the book she found that there was a considerable difference in temperature. She discussed this with Alison and the other children who had joined them and they repeated the experiment near the side of a radiator. More experiments followed as the children became interested in heat shadows and the absorption of heat by differently coloured materials. They suggested that a radiator was badly named since it did not only radiate heat, but also gave off heat by convection.

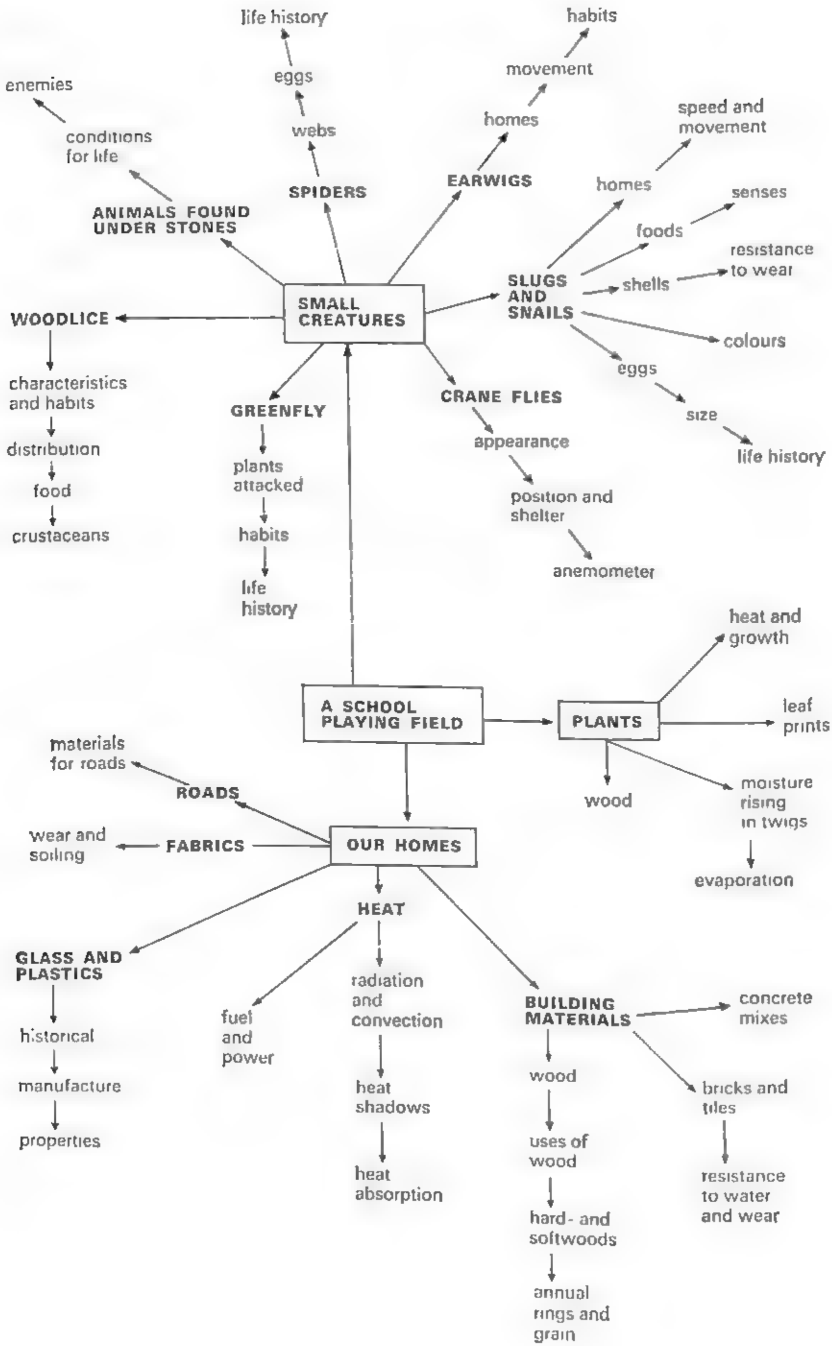
Some of the central heating advertisements which the children had collected referred to solid fuel. The children wanted to know more about it so they collected as many brands as they could and compared them. They soon discovered that gas and oil were also fuels because they were burnt to produce heat, but electricity did not burn and was therefore a form of power and not a fuel.

To round off the study, the children made a large chart showing different ways of heating a house.

Gillian and Judith studied timber used in the home. A builder gave them information about the kinds of timber which he used and supplied samples of each. They drove nails into hardwoods and softwoods to compare them, and then examined cross-sections of tree trunks which the teacher had obtained from a sawmill. They found that the annual rings were closer together in hardwoods than in softwoods and eventually concluded that close-grained woods are harder than those with an open grain. This led to work concerned with the rate at which tree trunks grow in diameter and to the uses and values of hardwoods and softwoods.

Pieces of carpet and furnishing materials were examined and tested for resistance to soiling and normal household wear. This might have been expected in a class composed almost entirely of girls, but when the caretaker cut his hand on a broken jam jar no one expected it to give rise to an investigation. Julie commented that it would be better if jars were made from plastic. The teacher, almost as an aside, replied, 'Yes, a lot of things in the home would probably be better made from plastic.' Much later, Julie and a group of girls asked the teacher if they could study the use of glass and plastics in the home.

They read about the manufacture of glass and plastics, and traced the history of glass-making. This brought them up against more problems, for example, what people used for windows before glass was made, and that led to further reading and study. They used small pieces of coloured glass to make a stained glass window, and then began to compare the properties of glass and transparent plastics. The girls felt that the greatest disadvantages of plastics were their low resistance to heat and the ease with which they were scratched. On the other hand, glass fractured easily on impact and the particles were sharp and dangerous. It seemed that one was not superior to the other but that it all depended on how they were to be used.


A SCHOOL PLAYING FIELD
SMALL CREATURES
ANIMALS FOUND UNDER STONES
conditions for life
enemies
SPIDERS
webs
eggs
life history
EARWIGS
homes
movement
habits
SLUGS AND SNAILS
homes
speed and movement
foods
senses
shells
resistance to wear
colours
eggs
size
life history
WOODLICE
characteristics and habits
distribution
food
crustaceans
GREENFLY
plants attacked
habits
life history
CRANE FLIES
appearance
position and shelter
anemometer
PLANTS
heat and growth
leaf prints
wood
moisture rising in twigs
evaporation
OUR HOMES
ROADS
materials for roads
FABRICS
wear and soiling
GLASS AND PLASTICS
historical
manufacture
properties
HEAT
fuel and power
radiation and convection
heat shadows
heat absorption
BUILDING MATERIALS
concrete mixes
bricks and tiles
resistance to water and wear
wood
uses of wood
hard- and softwoods
annual rings and grain

23 Sound II

Class	**9-10 years. Full range of ability**
Class number School roll	41 boys and girls 250
Term	Autumn
Building	19th century. Soon to be replaced.
Classroom	Large and spacious. Modern desks and furniture.
School environment	Facing an iron foundry. Gas works fifty yards away. Pupils drawn mainly from two new estates.
Local setting	North-east England. Small market town. Local industries clothing, synthetic fibres, agriculture.

The children were asked to bring to school anything which made a sound. On the following day a violin, a baby's rattle, a tin containing peas, a gramophone, and other objects were brought. These, together with a few school musical instruments, a tuning fork, and some books about sound were set out on a table. The children were interested and the teacher listened to their comments and questions as they played.

The children talked about their discoveries, then wrote down what they wanted to know about. This provided the teacher with enough information to draw up a list of topics:

1 Sounds and how they are made.
2 The pitch of sounds.
3 Amplification.
4 Transmitting sounds.
5 Sound insulation.
6 Acuteness of hearing.

There was a good supply of materials freely available to the children so that they were able not only to plan and perform their experiments, but also to display their findings.

After a brief discussion, the children chose the topics they wanted to study and formed groups based on their particular interests. Each group began by tackling a question, but looking back on this later, the teacher felt that the topics were too formal and, indeed, unnecessary. It would have been better simply to have asked the children to choose questions rather than topics.

Most of the work was done in groups, but there were periodic class discussions and occasional bursts of class activity, for example when an exciting discovery in one group commanded everyone's attention.

This is how the work of the different groups developed.

1 Sounds and how they are made

The children began by drawing up a list of as many sounds as possible and saying how each was made. They found that sounds were associated with vibration, for example, by putting sand on a drum, beating it, and watching the grains bouncing as the drumskin vibrated. The teacher also noticed that they were striking the tuning fork and then feeling the vibrating prongs. He left a jar half full of water on the table and soon Graham discovered that if he touched the surface of the water with a vibrating tuning fork, it made tiny waves.

The children were keenly interested in stringed instruments, and began to make their own. This is not surprising, since several of them played the violin, and various stringed instruments were included in the classroom display. They discovered that changing the length or the tension of a string altered the pitch of the sound it made.

While making a large harp from scrap materials, John noticed that the long wires vibrated slowly and made low notes while the short wires vibrated quickly and made high notes. He suggested to the group that the pitch depended upon the speed at which the string vibrated. The teacher introduced the word 'frequency' at this point and explained that the frequency of different notes could be measured. They now looked again at what happened as they tightened a vibrating string, and concluded that it altered the frequency.

This group made and experimented with various percussion instruments including drums, rattles, and a 'bottle xylophone'. They also recorded some common sounds and played them to the rest of the class, who were required to identify them.

2 The pitch of sounds

The children began by making stringed instruments and then followed a path very like the first group's. They experimented with strings of different materials and found in every case that the pitch rose as the string was shortened or tightened. Valerie made a simple instrument of a row of nails in a piece of wood with nylon fastened to them. Each string was made a little tighter than its neighbour. Figure 38 shows how she did this.

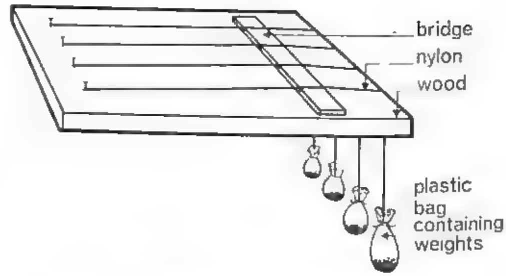


FIG. 38. Valerie's stringed instrument.

When one of the group suggested that the thickness of a string might affect the pitch of the note it made, Valerie's instrument was used to test the idea. Different thicknesses of string and nylon fishing line were tried.

The children soon found pictures of xylophones and asked if they could make some. The teacher provided some tubular metal and a few strips of oak, and the children read in a book that the bars should rest on rubber or felt strips. They found strips of balsa wood quite satisfactory. They also made nail xylophones, but considered them unsatisfactory because the nails did not vibrate very well.

The work of the first two groups overlapped to such an extent that they gradually merged.

Paul then brought a whistling kettle to school so that everyone could hear how the pitch of the whistle rose as steam pressure built up, and this prompted two girls to write a booklet on wind instruments explaining how their recorders worked. John also wrote about a cane flute he was making and Valerie added a section about a pedal organ. This booklet was a mixture of first-hand experience and material from books.

3 Amplification

The children pursued two main lines of enquiry. The boys experimented with an old gramophone to find out how they could make

the sound as loud as possible. They mounted a needle in a block of balsa and held the point in the groove of an old record on the turntable. Next they fixed the needle in the edge of a circular cheese box, then in the apex of a paper cone, and so on, until they could decide which needle holder made the most efficient amplifier. This was their own experiment which developed out of an idea they had found in a book. They found that their xylophones played louder on desks than on the floor and the teacher suggested that they should try a series of boxes. The girls began to experiment with sounding boards. They compared the sounds of a xylophone bar lying on the floor with those made when it was resting on balsa strips and on a wooden box. A boy who had been watching these experiments touched the box with a tuning fork and found that it amplified the sound. He felt sure that a bigger box would make it even louder and so collected a series of cardboard boxes to test his idea. Finally, he calculated the volume of each box.

The whole group made megaphones of different shapes and sizes and then used them as ear trumpets. Kenneth tried to explain this by saying, 'They brought the sound waves to a focus.'

They concluded their study by using tin cans to test the saying, 'Empty vessels make the most noise.'

4 Transmitting sound

The group that studied this included some of the most able children in the class. They started by making speaking-tubes from polythene funnels and rubber tubing, and when they had written descriptions of their construction and their uses, they showed them to the teacher. He felt they could take this further, and asked, 'How far will your voice carry along the tube?' They were keen to find out and tried the longest piece of rubber tubing they could find, only to discover that their voices travelled its full length. Then they made string telephones, an idea from a book, instead, and carried out some valuable

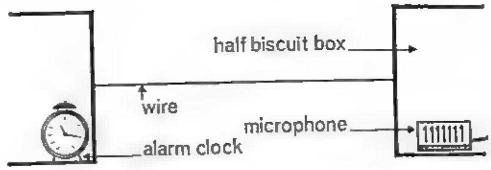


FIG. 39. The wire was replaced by twine. The efficiency with which they conduct sound was compared.

experiments with different thicknesses of string and different end cups in an attempt to improve transmission.

In the junk box was some fine wire, and two children used this to make a telephone. They tried to compare the efficiency of wire and string but this was difficult until they thought of using the tape recorder. Two halves of biscuit boxes were used with a small hole in the centre of the bottom of each one. They were then placed on their sides about six feet apart and connected by a piece of wire passing through the holes, and the children put an alarm clock in one and the microphone in the other (see figure 39). They then replaced the wire by a piece of clothes line, repeating the process until they had recorded the sound transmitted by many different strings. Finally they played the recording several times and decided which connection was best.

From a book, they got the idea of tapping the central heating pipes to see if sound would travel through metal, and it was then that Eric asked if sound travels through water. He asked the teacher for a tube to fill with water, and was given a plastic one about three feet long and an inch in diameter. He looked for corks to put in each end, but as there were none, he brought two table tennis balls and asked if he could use them. He stuck a ball into one end of the tube, using impact adhesive, filled the tube with water, and closed the other end with the second ball. He then clamped the tube horizontally, struck a tuning fork, and put it on the ball at one end. His friend who listened at the other end could hear it clearly.

The teacher said little at this time, but a day or two later he asked whether the sound could have travelled from the tuning fork to

his ear without passing through the water. Eric said at once, 'Oh, of course! It could have gone along the plastic tube.'

He was determined to prove that sound could travel through water, so he used a sleigh bell and an aquarium half full of water. He held the bell under water, shook it, and pressed his ear against the glass.

Following a conversation about Red Indians listening for the sound of horses' hoofs, the children decided to find out if sound really did travel through the ground. They found a crack in the concrete playground, put the point of a long nail into it, and tapped the head with a hammer. They could hear the sound seventy-four yards away through the ground even though they could not hear it through the air.

Although most of their work involved first-hand investigation, the children loved reading and they searched in books for more information. It was hardly surprising, therefore, to find that they decided to write a booklet on modern methods of communication. It began with a brief account of the life and work of Marconi and included chapters on Morse code, semaphore, telephones, and radio.

5 Sound insulation

The group began with the question, 'How can we insulate a room from sound?' To find out what substances were good insulators, they selected a range of materials and used each, in turn, to cover an alarm clock. They measured the distance from the clock at which the sound became inaudible and presented their results as a block graph.

It was generally agreed that the sound of a transistor radio was one of the biggest nuisances in a house, so they decided to see how effectively they could insulate a room against it. They found a large cardboard box and made a compartment inside it just big enough to hold a transistor radio. The space between the compartment and the sides of the box was then packed with materials which had been found to be the most effective insulators. When the children turned on the radio and lowered it into the box, the effect was dramatic. The teacher suggested that they should take the tape recorder to the school gates and record street noises. Later, after listening to their recording, they suggested ways of reducing the noise. Amongst other things, they thought that plastic milk bottles would be a welcome innovation for those who were awakened early in the morning by the milkman.

6 Acuteness of hearing

'How do we hear?' This was the question engaging the attention of the sixth group, and they found themselves working mainly from books. They read about the human ear and drew a diagram showing its structure, then jotted a few notes about acuteness of hearing in animals. They listed the frequencies of sounds made by musical instruments and read about the range of hearing of various creatures, including humans. Some notes on bats, and how they navigate, were included.

When, near the end of term, they asked the teacher to tell them more about sound waves and what they are like, he enlisted the help of a science teacher from a nearby secondary school. He showed them a film about sound waves, and set up an oscilloscope so that they could see the trace made by their own instruments and tuning forks.

The whole class became involved when Linda announced that sound travels at 650 miles an hour. When the teacher asked how it was measured, two boys said that you had to make a sound and see how long it took to travel a mile. During the discussion which followed the teacher asked whether a firework would be of any use, and they thought it would be ideal.

The children, who can be seen in figure 40, chose a long, straight cart track between two fields and measured a quarter of a mile. They tied a firework to the end of a long stick so that it was visible from a distance, and stood it upright. As each firework went off the

FIG. 40. Finding the speed of sound.

children at the other end of the cart track timed the interval between seeing the flash and hearing the bang.

An extract from Linda's notes reads:

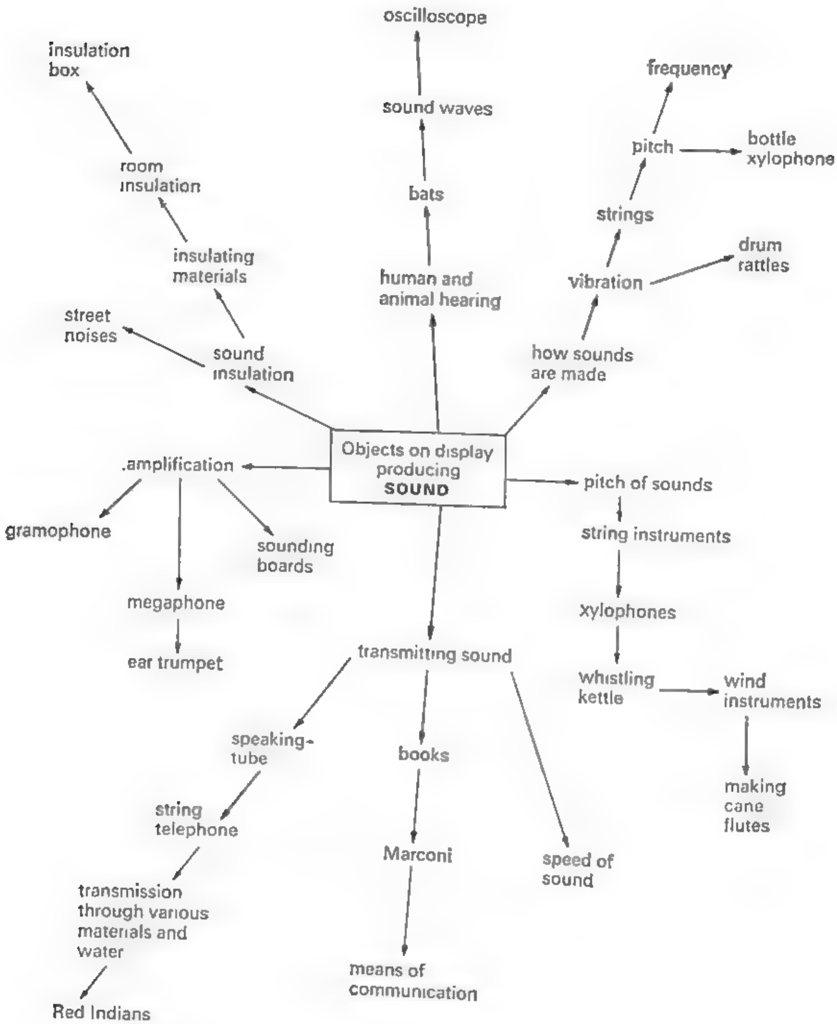
'My teacher and the boys didn't see the flash and then hear the bang. They saw the flash and heard the bang together. Because they were right under the sound. And it took less time to get to them. But we were a quarter of a mile away and it took time to reach us.

1st time $1\frac{1}{2}$ seconds.
2nd time $1\frac{1}{5}$ seconds.
3rd time $1\frac{1}{5}$ seconds.
4th time $1\frac{1}{5}$ seconds.

I think the first time when I got the result of $1\frac{1}{2}$ I wasn't quite ready. So we took the time as $1\frac{1}{5}$.'

The children timed how long it took them to walk back to school, and this was the beginning of an interest in speeds. They found out how fast they could walk, run, cycle, and skip, and then looked up the speeds of animals, birds, and aeroplanes.

Katherine read about the eruption of Krakatoa and then wrote a description of it, drawing a map showing all the places where the sound was heard. Eric rounded it off by working out the time at which the sound reached different places.



oscilloscope
insulation box
frequency
sound waves
bottle xylophone
pitch
room insulation
bats
strings
drum rattles
insulating materials
human and animal hearing
vibration
street noises
sound insulation
how sounds are made
Objects on display producing SOUND
.amplification
pitch of sounds
gramophone
sounding boards
string instruments
megaphone
xylophones
ear trumpet
transmitting sound
whistling kettle
wind instruments
speaking-tube
books
making cane flutes
string telephone
Marconi
speed of sound
transmission through various materials and water
means of communication
Red Indians

24 A story read to the class

Class	**9-10 years. Lower stream of two-stream school**
Class number School roll	36 boys and girls 503
Terms	Spring and summer
Building	Built in 1877
Classroom	Old and dark. Rather cramped.
School environment	Small market town. School surrounded by asphalt play-ground and fields. Stream nearby.
Local setting	East Midlands. Market town in agricultural area. No local industries other than farming.

The teacher had taught science previously, but in a very formal way. He had decided to try a more informal approach and was waiting for an opportunity to present itself. The chance came when he read the class the story of the 'Pooh-sticks' from *Winnie-the-Pooh*. When the sticks were dropped into the stream from the bridge, what made them come on the other side? he asked. He was surprised when the children said, 'The wind blew them'. He then took up the problem with the whole class, first discussing how to make water move along an old piece of guttering.

Three boys raised the question of how speed was related to slope, and devised an experiment with a long piece of wood, raised at one end, a glass marble, and a stopwatch. It was as a result of this that one boy said, 'I don't need to write about this, I can draw it in a graph', and proceeded to construct his first continuous-line graph. (He had previously drawn block graphs.)

There were questions about the camber of the road. Someone asked if the very slow-moving nearby stream really sloped. How do rivers start? To find an answer to this last question two boys used clay to build a hill with gullies down which water could be poured. The teacher then produced plastic funnels and tubing so that the boys could investigate the effect of water level on flow.

One of three girls watching the boys build the clay hill asked the others why clay was used. They decided that it was partly because it could easily be moulded and probably because it did not allow water to soak through it. The teacher then asked them what happened to rain which fell on different kinds of soil. The girls found out by putting clay, loam, and sand in empty milk bottles and pouring water into them. One of the girls said that she thought the rain would soak into some stones, so they stood a piece of the local limestone in water in a tin and included a

housebrick for good measure. Next day, when the stone and the brick were broken, it was obvious that the water had soaked into each of them. One of the girls followed this up by visiting a local building site to ask how the builders prevented water from soaking through the walls.

Meanwhile, another group had added a dam wall to the gully in the clay hill and had noted the flat surface of the water. 'Was it really flat?' asked the teacher, and one of the boys responded by bringing to school a spirit level and placing it on a piece of balsa wood floating on water.

One girl experimented at home with different kinds of paper and cloth as a means of getting a needle to float.

One group had asked about the drying up of puddles, and at this point the teacher brought fruits and potatoes into the classroom, and left them on the table. The children had placed dishes of water in shady and sunny places to compare the rate of drying, left another dish exposed in the room, and placed yet another in a closed tin box. The holiday interrupted this experiment, and the children returned to find the exposed dish dry, while inside the tin box the dish was still half full. Drops of water on the inside of the box led to a discussion on condensation.

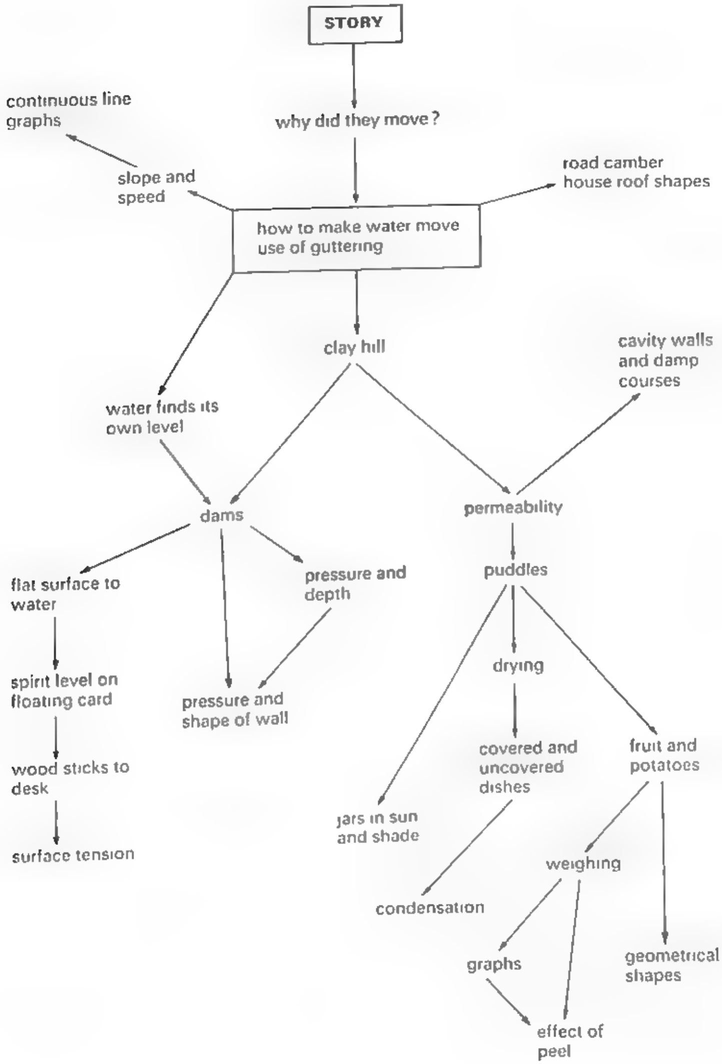
The fruit and potatoes were now given some attention and three girls decided to weigh them to find out if the shrivelling was due to loss of water. They did this, starting with fresh material, and graphed their findings. The teacher then asked them if the peel of the fruit had any effect, and they did a new series of weighings, this time using peeled fruit, and unpeeled fruit as a control.

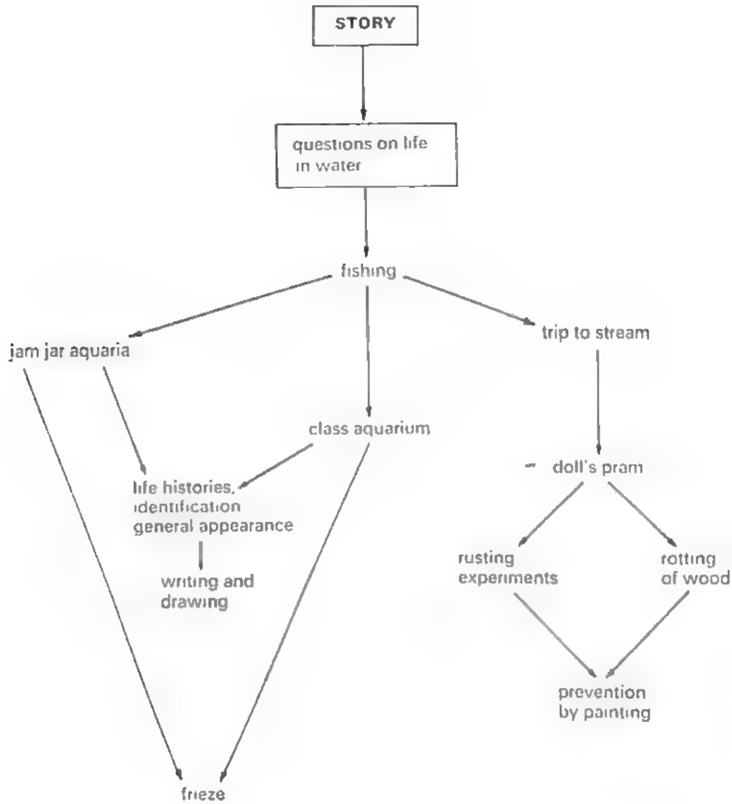
At this stage, the teacher decided to round off the work and to take up the questions the children were already asking about life in water. A trip was arranged to the river and a good sample of aquatic creatures collected. Each child kept selected animals in a jam jar, and the whole class set up and maintained an aquarium.

There was a great deal of careful observation and searching in reference books for information, much of which gave rise to writing and drawing. The children also used this work as the basis for a collage frieze.

A visit was arranged to another stream, ostensibly to look at the flora. In fact, the discovery of an old doll's pram in the water started the children talking about rusting instead. Which things rust? Do all metals rust? What makes them rust? How can we prevent them from rusting? If wood does not rust and if metal is painted to stop it rusting, why do we paint woodwork?

These were the sorts of questions which provoked and kept going an investigation into rusting, its causes and prevention, until the following term ended in July.


STORY
why did they move?
continuous line graphs
slope and speed
road camber house roof shapes
how to make water move use of guttering
clay hill
cavity walls and damp courses
water finds its own level
dams
permeability
flat surface to water
pressure and depth
puddles
spirit level on floating card
pressure and shape of wall
drying
wood sticks to desk
covered and uncovered dishes
fruit and potatoes
jars in sun and shade
surface tension
weighing
condensation
graphs
geometrical shapes
effect of peel


STORY
questions on life in water
fishing
jam jar aquaria
trip to stream
class aquarium
life histories, identification general appearance
writing and drawing
doll's pram
rusting experiments
rotting of wood
prevention by painting
frieze

Continuation of frieze

PLATE 6 (*above*). Twelve-foot frieze showing rock pool (p. 95).

PLATE 7 (*right*). Painting done after a visit to a country estate (p. 118).

PLATE 8. The children's paintings became less and less representational (p. 148).

PLATE 9. Paper and wire model of a wasp (p. 148).

25 A visit to the school grounds

Class	**9-10 years. Full range of ability**
Class number School roll	32 boys 350
Term	Autumn
Building	Attractive, with modern facilities.
Classroom	Pleasant, light, and airy. Wall blackboards, display space, modern furniture. One electric point. Water supply.
School environment	Suburban. Large playing field with hedgerow and unmown waste area. Serving rapidly expanding residential area.
Local setting	North-east England. Suburb of large town which has heavy industry.

The teacher took the boys into the school grounds to see what living creatures could be found there. Most of them ignored the lawns and football pitch and began searching in an unmown grassy area. Their finds included spiders, snails, slugs, millipedes, centipedes, woodlice, earwigs, snails' eggs, and a wasp's nest. A small group of boys began to look in the hedgerow, where they found a dead shrew and some fungi. As they searched, they found the runs and burrows of field voles and spent a long time examining them.

Some children later sought reference books to identify their specimens, but others just wanted to watch and examine theirs. All of them housed their creatures so that they could keep them for further study. Plastic lunch boxes with holes drilled in the lids were found most useful, but empty aquaria and jam jars were also used.

Next morning, David's slug was missing from its jam jar. It was eventually found on a damp branch which had been brought into the classroom for the fungus growing on it, and on which the slug was feeding. David was quick to suggest that the slug must have been seeking either food or dampness and that they really ought to find out more about what their creatures needed to eat and what kind of conditions they lived in. The children each took a pencil and notebook and went out into the grounds to see where animals lived. This time they did not collect specimens but jotted down where the creatures were found; under stones, on plants, or in rotten wood.

They made a large chart to show what they had discovered and this helped them to decide what conditions were necessary for many of their creatures, as well as leading to some interesting observations. Jeremy pointed out: 'A surprising fact is that only a third of

the creatures found under stones were also found under logs. Both conditions are similar.' He also observed, 'No legless creature was found in dry conditions.'

Ultimately, the boys formed five groups to study the creatures they had chosen. These were worms, slugs, spiders, snails, and wasps. Most of them appear to have been chosen because they were plentiful and because the children could find some information about them in their own class library. A wasp's nest which had been brought into the classroom undoubtedly influenced the group who chose wasps, and it gave rise to studies which went on for most of the term.

Group work developed as follows.

Worms

The children concerned began by examining worms very carefully. They measured their length when contracted and extended, comparing one with another. When they counted the number of segments on several worms they found that the position of the clitellum varied. Turning to reference books for an explanation, they learned that they had collected both earthworms and longworms. Studying an earthworm under a binocular microscope, Andrew noticed that its skin was wrinkled and thought that this must allow it to stretch as the worm moved. The children made many detailed drawings.

Wormeries were used for some simple investigations. One end of a wormery was left dry and the other moistened to see to which end the worms would go. Various foods were introduced to find out which would be eaten. A wormery was covered with a piece of black material and the worms burrowed alongside the glass. Whenever the cover was removed, any worms which were exposed to light immediately withdrew into the soil. The children thought this showed that worms could detect light and moved away from it in case enemies, like birds, should see them.

Andrew wanted to weigh a worm but found that a spring balance was not sensitive enough so he made one from a thin elastic band. When he found that the band was too strong, he cut it in half along its length to make it stretch more. It was still not sufficiently sensitive, so he made another balance using a fine helical spring. This time he found that the weight of one worm was enough to make the spring extend appreciably. He calibrated the balance by weighing out a quarter of an ounce of Poppit beads, calculating the weight of one, and using this to give him a unit. His worm weighed $\frac{1}{32}$ oz. Although he had succeeded in doing what he had set out to do, he went on making balances of different kinds and weighing light objects.

Three of the children thought that the number of worm casts which appeared on the school lawn was related to the weather. They decided to mark out a number of separate square yards on the lawn, count the number of worm casts in each one every day, and relate this to the weather and the soil temperature. They believed that when they had collected this information for a few weeks they would be able, if given the soil temperature and weather conditions, to forecast how many worm casts they would find. Progress was slow, mainly because the first two soil thermometers which were tried proved to be too frail for nine-year-old boys to handle. No forecast was ever made, but other things developed. The boys suddenly announced that they could estimate the worm population in the lawn if they calculated the area in square yards and multiplied this by an average number of worm casts which they found in a square yard. This was done, and when they produced their figures the boys said that they were only approximate, for, apart from other factors, they could not be sure that every worm produced a cast.

Slugs

David put some sand in a plastic box, making one end dry and the other wet, and put his slug in the middle several times to see which end it would choose. This confirmed his previous findings. He and the rest of his group offered their slugs a variety of foods,

including toadstools, lettuce, carrot, and apple, to see which they would eat. The children suddenly realized that although they could see where the slugs had been eating a piece of food, they had no idea of how they ate. Therefore they placed one slug on a piece of transparent acetate film so they could watch it from below as it ate. Tests were also made to find out whether slugs could smell and see.

The children used hand lenses to examine the slugs. The respiratory aperture in the mantle of a large slug was soon identified and the pupils were also most interested in the tentacles and their sensitivity to touch, and made detailed sketches.

The children measured a slug when it was contracted and when it was extended, and then made drawings of it in both positions. It occurred to them that human beings could also extend and contract themselves, though in a different way, so they used tinted cardboard, jointed with paper fasteners, to make a model man who could be stretched out and curled up. This led to work on joints, bones, and muscles.

Next, they timed how long it took a snail to travel an inch and calculated that at a constant speed it would take twenty-two days to cover a mile. Christopher and David wondered whether slugs moved in different ways over different surfaces, so they persuaded one to cross sand, soil, grit, pebbles, glass, and other surfaces to see what happened. They concluded that the surface made no difference, for it used its slime on all of them and moved in the same way. They noticed that when a slug travelling over a desk crossed a crack, the slime trail continued over it, forming a bridge of slime. Baby slugs made yellow slime, while adults' was whitish or colourless.

Spiders

When a spider died, the group used a binocular microscope to examine it. Large drawings were made of its head, jaws, eyes, legs, and spinnerets, and the degree of magnification was indicated. They drew the compound eyes of a wasp and the simple eyes of a spider side by side, to show the differences. Underneath they listed other differences between insects and spiders.

Brian drew a map of the school grounds showing the places where spiders had been caught. It provoked a great deal of discussion. Others sought reference books to find out more about their spiders. They read about their habits and life histories and, in the light of this information, looked with fresh eyes at their specimens.

As a spider spun its web in one of the cages, the children drew a series of sketches showing its construction. They put small insects into the web to see how they became entangled and to find out what the spider would do. Webs were collected and examined under the microscope alongside human hair and a variety of fibres.

In addition to their writing and sketches, the children made many attractive paintings and lino cuts of spiders and their webs, while John made a large model of a spider.

Snails

The children in the group found that snails seemed to like cool, damp, dark places. They therefore chose a large glass trough as a suitable container, put soil, stones, and plants into it, watered it well, and kept it shaded. The snails remained active and healthy.

Like the other groups, they spent a lot of time handling and observing their specimens. They watched them feeding, discovered how snails breathe, and saw the muscular rippling of the foot as the snail moved across a sheet of glass. In an attempt to find out which foods a snail prefers, they put a selection in a ring and placed the snail in the centre. It ignored all the food, so they had to devise a different approach to the problem.

Martyn noticed that the outer layer was peeling off an empty shell. He thought that it looked just like varnish and was possibly used to colour the shell so that birds could not see it very easily. The teacher suggested that he

should put the shell in vinegar. Other children gathered round to see what happened and soon there was a lively discussion as they tried to discover why bubbles were rising from the part from which the outer coating had peeled off.

A close examination of one of the snail's shells showed that it had a hole in it which had been plugged with chitin. This made the children wonder how strong snail shells were.

They thought about the kind of wear and tear they would have to withstand and devised ways of testing their resistance to wear and to impact.

Their paintings of snails were representational at first but soon became much freer and more decorative. One of them can be seen in plate 8.

Wasps

The pupils in the group collected dead specimens and examined them under the microscope. They also tried to discover by experiment whether wasps find food by sight or smell, but their main interest lay in the wasps' nest. They considered its properties as a home for baby wasps. Was it waterproof? They confirmed this by sprinkling water over it from a can. But was it waterproof because of its shape or because of the material from which it was made? They made roofs of many shapes from stiff paper and decided that shape was important.

To find out whether the nest retained heat, they filled two similar tins with hot water, put the wasps' nest over one like a tea cosy, and waited to see which cooled first.

Paul asked how wasps made paper. They looked it up in a book and found a description of how wasps gnaw off shavings of wood, chew it, and make it into a pulp which hardens into paper. Deciding to make some paper in a similar way, the children mixed pencil shavings with cold water paste and then chopped up the mixture with a knife. This produced a very rough material, not at all like wasp paper. They then shaved wood off a broken ruler with a razor blade. It was a slow and laborious process, but they added glue and it produced a finer grade of paper.

Still far from satisfied, the group went in search of wood which they could make into a very fine pulp. They found some at the bottom of the school field—soft dead wood in an old tree stump. They passed this through a pencil sharpener and mixed the shavings with glue. The teacher writes:

> 'This produced their first real-looking paper, rather like egg cartons. It was put under the microscope and then the newspaper was put under, and the two appeared to have very much the same pattern.'

By this time the boys had asked for other kinds of glue to see if these would improve matters. They found that balsa cement was the most satisfactory, but the first time they tried it, it dried so quickly that the mixture set in a lump. They solved this problem by mixing the sawdust with water, making a pulp, and then adding the balsa cement.

In an attempt to get an even finer paper, the boys passed their sawdust through a sieve which consisted of a piece of perforated zinc over a jar. When they mixed the new dust with glue they achieved a texture finer than anything so far achieved but still not as fine as the wasps' paper. At this point the headmistress came to their aid, supplying a muslin sieve. This was just what they needed and they produced paper which was almost as fine as the wasps'.

After this piece of sustained experimentation, Kevin made a large model of a wasp, shown in plate 9, by building up layers of paper on a wire framework. The others examined the cells and brood inside the nest, and traced the history of the wasp, comparing the contents of the nest with the account in a book.

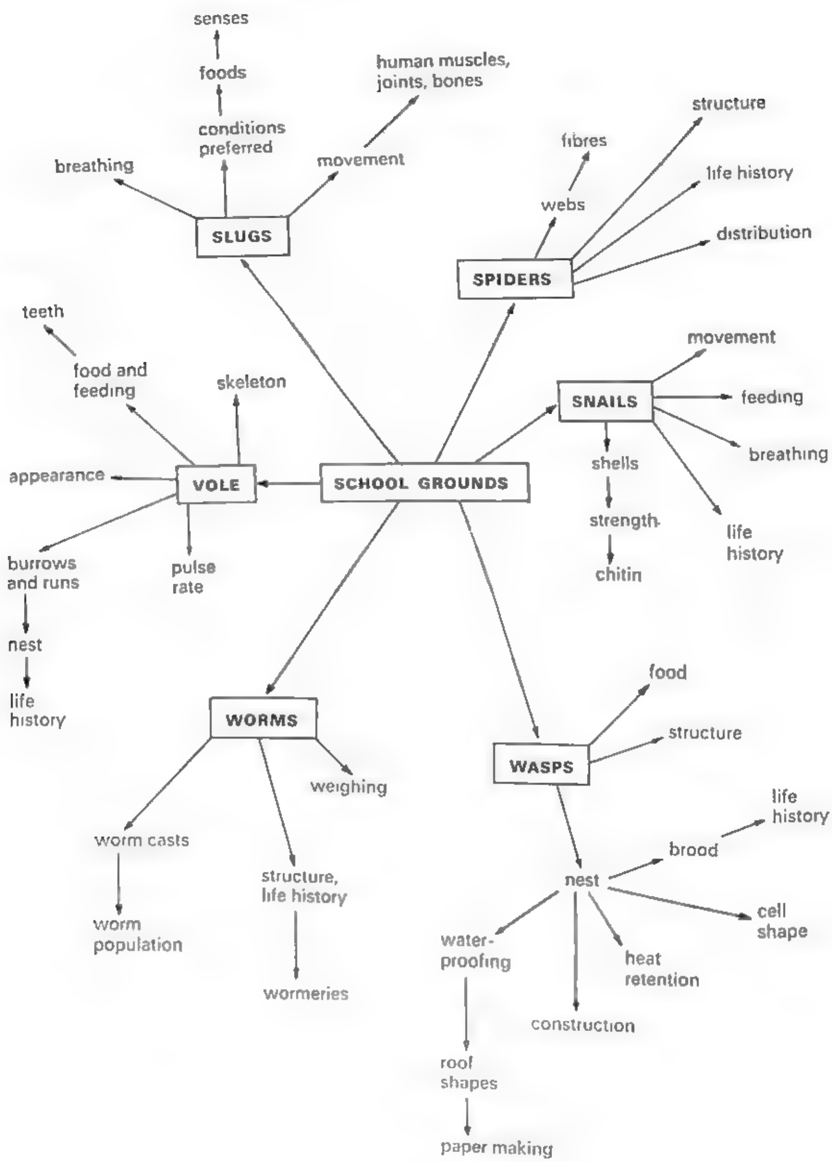
A sixth group formed when Nigel caught a field vole. He filled a glass tank half full of soil for it to burrow in and put turf on top. Then the group provided food and water, and made a piece of perforated zinc into a cover. The vole burrowed into the soil and settled down in its new surroundings. Soon it

became so tame that the boys had no difficulty in handling and weighing it. They put straw in the cage and watched the vole drag it into its burrow.

Nigel and two other boys wrote a booklet describing the vole's appearance, habits, and food preferences, and telling what they had found out about voles from reference books. They made plaster casts of its footprints and of the teeth marks which it left in pieces of apple. This led to a study of its teeth and how it used them.

While they were handling the vole, the boys felt its bones and counted its pulse rate. They noticed that this seemed fast and compared it with their own after they had been sitting, walking, and running.

Voles' runs and burrows in the school grounds were mapped, and an empty vole's nest was found.


senses
foods
human muscles, joints, bones
conditions preferred
breathing
movement
SLUGS
fibres
structure
life history
webs
distribution
SPIDERS
teeth
food and feeding
skeleton
movement
SNAILS
feeding
breathing
appearance
VOLE
SCHOOL GROUNDS
shells
strength
chitin
life history
burrows and runs
pulse rate
nest
life history
food
structure
WORMS
WASPS
weighing
life history
worm casts
brood
structure, life history
nest
cell shape
worm population
water-proofing
heat retention
wormeries
construction
roof shapes
paper making

26 Bricks and glass

Class	9-11 years. Full range of ability
Class number School roll	35 boys and girls 238 (5-15 years)
Terms	Autumn and spring
Building	19th Century. Dark and unattractive.
Classroom	Crowded. High windows. Modern desks, and a few side tables. One woodwork bench.
School environment	An industrial riverside with waste ground, railways, clay pit, disused mineral line, and dene. Beyond are the cooling towers, chimneys, pylons, and dirt of many industries.
Local setting	North-east England. Urban area. For centuries, coal-mining flourished; now there is one mine. Chief industries: brick-making, glass, chemical and light engineering.

Bricks

The heavily industrialized environment of this school offered much scope for study. When the matter was discussed with the class, it was obvious that a visit to the brickworks would be popular. Thus, bricks were the first man-made materials chosen for study.

Visit to a brickworks

There are several brickworks within easy reach of school; one was selected as the 'best' and Maureen volunteered to write for permission to visit it.

At the brickworks the class divided into three groups and these were assigned to guides. The teacher joined one group, and the Nuffield team leader accompanied another. The route from raw material to finished product is quarry to mixing plant to machine shed to kiln. One group followed this course, but to avoid congestion, the other parties started along the production line. Soon the children were talking freely to their guides and it became clear that there were two contrasting sets of questions being asked by the children. The first (prepared questions) came early in the visit and were as follows:

'How do you colour bricks?'
'Why do you colour a brick?'
'Do you make different sizes of bricks?'
'How many bricks do you make a week?'
'How much do the men get each week?'
'How many men work here?'
'How many in the office?'

These questions were not followed up by the

children after the visit. Spontaneous questions came later during the conducted tour when the children were really involved:

'Why do you make bricks square?'
'What brings them [the bricks] in here [a kiln]?'
'What's that?'—on seeing a mechanical dumper.
'Are they spoiled?' [They were spoiled bricks.]
'Are they [spoiled bricks] wasted?'
'How big is the chimney?'
'How many bricks are there in the chimney?'

The last two questions were asked by children in two of the parties independently.

The questions—additional to the details imparted by the guides—were answered directly and simply in a language the children could understand. But, as on many industrial visits, the guide could be heard only by those closest to him.

The action of the machine shed and the kilns had the greatest appeal to most of the upper juniors. Many of the boys displayed interest in the works machinery, especially in the grab, electric shovels, dumpers, and electric forks. But they were even more pleased to be given a card and allowed to clock in, for this was indeed contact with the real thing. Collecting was encouraged, and at the end of the visit the three groups had large quantities of clays (crushed and uncrushed) and bricks of different types, various colours, spoiled and perfect.

On returning to school next day, everyone, including the slowest learners, wanted to write about the outing. To bring more order to the recording, the teacher broke the class into four groups, and group folders soon carried titles such as 'Man's Use of Clay'. The visit had given the children much to think about and the resulting writing was personal, vivid, and often couched in technical terms. Some dealt with the outing in chronological order, others wrote about specific objects or happenings. Many of the drawings, especially those of the boys, reflected their interest in machines and vehicles, and frequently showed awareness of detail. Lawrence combined observation and imagination in a short poem entitled 'Wagons'. Soon smaller groups began to extend the record of the visit. One group produced a life history of a brick which incorporated art and craft. You can see part of this in plate 10. The boys used the time when the girls were doing needlework to build a large—but not scale—model of the quarry and brickworks. On foundations of large cardboard boxes, hardboard, and sheets of well pasted paper went clay from the quarry, cardboard, cloth, wool, Plasticine, hawthorn twigs, model bulldozers, and Meccano parts. The finished model was a colourful representation of the industrial site and it brought much satisfaction to its builders.

During the visit, two children had asked a question which was later referred to on several occasions. This was, 'How many bricks are there in the works' chimney?' How could this be answered? After a long discussion, it was decided that a square yard could be drawn on a wall of the school and the bricks in it counted. This then gave a standard from which the number of bricks in a wall or any known area could be calculated. One group continued to count the total number of bricks in the school wall, then calculated its total area and assessed the value of the 'square yard standard'. This example was followed by other groups, and to avoid repetition, the teacher suggested that each examine different walls. Approximations resulted because of many half bricks having been used. In addition, the walls were old and it was soon discovered that the size of the bricks themselves varied.

The children realized that the means of determining the number of bricks in a known area could not be successfully applied to a tapering chimney stack, so it seemed as if the problem would not be satisfactorily solved. However, Claire, one of the two who had posed it, pursued the question at home and with both parents visited the brickworks one evening. They were told by the works' foreman that 300,000 bricks had been used

to build the stack. Claire and her classmates seemed satisfied.

From the variations in the size of bricks in the school walls there arose an interest in the differences between bricks themselves, and it was clear that a classroom collection was needed. Soon, bricks began to appear in large numbers, the two best sources being the waste ground nearby and the school garden. When there were thirty-five bricks, or the equivalent of one per child, no more collecting was allowed. Each brick was then measured and weighed, and to its 'record card' was added:

The maker's name and its date (if shown).
Its colour.
Its possible use.
Where found.

Many of the samples were broken to find whether or not they had been well fired (interior clay red) and it was found that most of the older bricks had been poorly fired (blue) and had been made from local clay. Similarities and differences in the bricks in the collection were drawn and others became apparent when the results were tabulated.

The clay pit

After the brickworks visit the children often talked about a clay pit some five hundred yards from school. It was clear that many in the class thought that they should visit it and compare it with the one at the works. So at a point when the classroom work with bricks was losing momentum the teacher suggested doing this.

Work in the quarry had ceased the previous year but part of the line of the mineral track was visible. The children called this the dilly wagon track and it obviously brought back memories to many of when the quarry was active. Before reaching the clay face Christopher unearthed a pick head and asked, 'Is this what they used?' Some thought it was, while others suggested that a grab—like the one in the brickworks quarry—must have been employed. But David, whose father had worked in the quarry, settled the issue when he declared that a mechanical navvy had been used and that they only resorted to picks when this was out of action.

Before leaving school, the class had been divided into eight groups, but in the quarry they wandered freely and followed their own interests. Other finds included a section of a drain pipe made from clay and several rounded sandstone pebbles. Polythene bags were soon bulging with blue, brown, orange, and white coloured clays. One group of four girls continued to work together in collecting as many (single) flowers and plants as they could find. This group paid particular attention to the root types of the plants collected. When pulling plants from the ground they were having to tug hard and when asked by the teacher how they could measure the pull required (for different plants), Theresa thought it might be possible with the help of a spring balance. That afternoon in school various seeds were sown in pots of clay, sand, soil, and mixtures of these three. A few days later some of the girls were upset when someone watered their pots so much that water remained almost an inch above the surface of some. Susan gave the reason for the flooding: 'The clay is holding it.' The progress of the germination experiments was carefully followed and the results recorded in due course.

There were further experiments with bricks. The teacher suggested to one group that they might stand their bricks in water for twenty-four hours and see what happened. Next day when they were removed from the water they seemed wet, but nothing more. Philip thought that if the water had been coloured it would have changed the bricks' colour. Soon dry bricks were standing in water well coloured with black ink and to the children's delight the

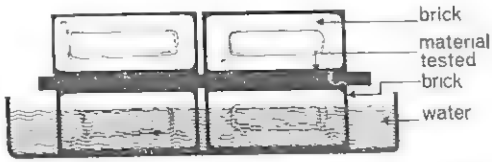


FIG. 41. Experiment to test damp course materials.

BRICK	DATE	MADE	CONDITION
A	1964	Throckley Brickworks	Perfect
B	1962		Slight crack on one face
C	'Very old'	Unknown	Good
D	1964	Throckley	Perfect

FIG. 42. How the boys recorded the bricks before testing.

FIG. 43. How the boys recorded results after testing.

BRICK	IN FURNACE	TREATED	RESULT
A	3 hours	Plunged into cold water	Covered in fairly large cracks. Otherwise in good condition.
B	24 hours	Allowed to cool gradually	Cleaved neatly in half along the crack. Reduced in size. Weighed less.
C	24 hours	Allowed to cool gradually	Shape altered ; seemed to have shrunken. Weighed less.
D	72 hours	Allowed to cool gradually	Badly mangled with coke and clinker sticking to it. Easily broken with a hammer.

bricks eventually took on a blackish tint. The bricks were like clay and soaked up water. This consideration was quickly extended when Carol wondered how much water could be soaked up. Her first step was to stand a brick in water with a line drawn round it at the water level. When Lynn pointed out that water might be lost from the basin (by evaporation) as in the aquarium, Carol replied that she would weigh the brick and find out how much water had been absorbed because she already knew the weight of the brick when dry. This exercise was repeated for periods of twenty-four hours, forty-eight hours, seventy-two hours, and one week, and later the equivalent amounts of water absorbed were displayed in bottles alongside the bricks used.

Philip was responsible for an extension to the water absorption work when he mentioned that someone in his street was building a garage and after laying the foundations put some 'special stuff' on top of the bricks before he continued building. Some thought that the special stuff was felt, others said wood. When the teacher asked why this stuff was laid between two layers of bricks, the work of Carol and Lynn and the observation of Philip were quickly related. The outcome was that they tested possible damp course materials with two layers of bricks and a tray of water, as figure 41 shows.

George and William were anxious to find what happened to a brick when it was heated and began by leaving one on a gas ring in the school kitchen. After thirty minutes they pushed it into a pail of cold water. They watched bubbles appear on the surface of the brick and later found small cracks. How could they heat more strongly and possibly obtain a greater change? The teacher thought that the school caretaker might be approached and asked whether the furnace of the school boiler could be used. The caretaker proved willing and four bricks were selected for heating.

George and William classified the bricks as shown in figure 42, and recorded the results of their tests as in figure 43. Then they told the class about their findings.

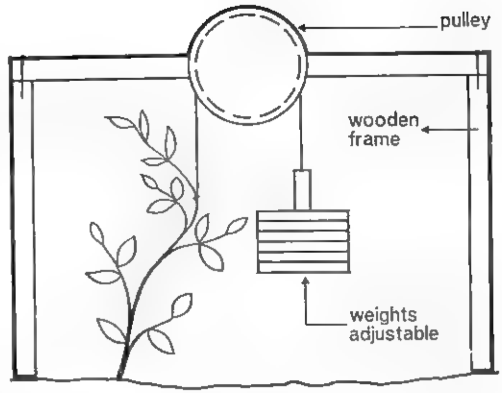


FIG. 44. Apparatus for pulling up a plant and measuring the strength of pull needed.

Second visit to the clay pit

Lawrence and James had joined Theresa in building a piece of equipment (see figure 44) which they hoped would pull plants from the ground and measure the strength of the pull required. They asked if they could return to the quarry to test it out.

In action, the apparatus was not up to the task in hand. Although the ground was partly frozen at the time, the equipment was too unstable and the three constructors finally resorted to a spring balance. They tied this to the middle of stems and pulled. Results were obtained, but when a plant was not extracted with its roots intact it was counted as a failure and not recorded. Some failures occurred with a maximum pull of fifteen pounds. While the spring balance had provided results Theresa, Lawrence, and James still felt that their apparatus could be modified to be successful. The rest of the class had the freedom of the quarry. New finds were a well used shovel, iron bars, and a few nuts and bolts. The latter, Paul suggested, had been used on the dilly wagon track.

The colours of autumn were greatly advanced since the time of the last visit, as several children remarked. Susan said, 'You would think that this place was on fire. Look how red it is.'

Still more clay was taken back to the classroom, and when it was added to that from the first two visits it caused a storage problem. The teacher indicated that something would have to be done about this, so many in the class decided to model with the clay. This was not a new practice, but when David asked whether they might fire their models, he set a new problem. The teacher was at a loss to know how to build a kiln and no worthwhile ideas were forthcoming from the class. Here was a case when expert advice was required and this was obtained from the Art and Crafts Department of a nearby College of Education. Plans were provided for sawdust and coke-fired kilns and the task of building a sawdust kiln was entrusted to two of the slower-learning ten-year-olds in the class, David and Christopher. Figure 45 shows them at work.

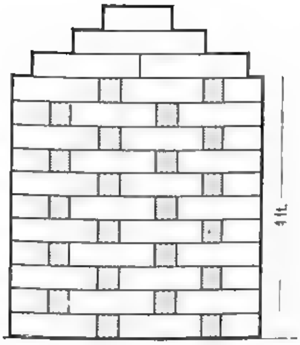
After a piece of ground had been levelled in the school garden, a kiln was built in thirty minutes—so quickly that with a plentiful supply of bricks available there was time to erect a second, similar one. The structure is shown in figures 46, 47, and 48.

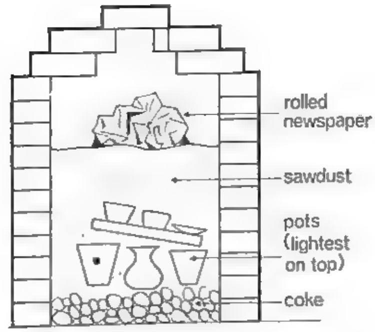
The first firing failed because some of the sawdust was damp. The next attempt in the second kiln was, however, entirely successful. Instead of using paraffin to start combustion, rolled newspapers and two candles were sufficient. When the newspaper was ignited, late one afternoon, it was not certain that the sawdust was alight, but when the kiln was visited the next morning the children were thrilled to find that the sawdust had burnt through to the base. The interior of the kiln and the pots were still extremely hot and it was left to an excited David and Christopher to remove them.

Some of the pots had broken, but most were successfully fired, and where the children had burnished the clay with a piece of wood it was recovered smooth and shiny.

The term ended before sufficient fire-bricks had been acquired to build a coke-fired kiln. But the children were determined to tackle this next term. The success of the primitive

FIG. 45. David and Christopher building a kiln.





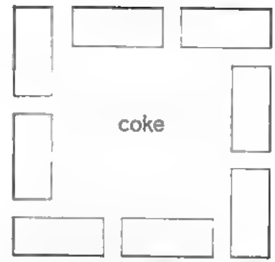


FIG. 46 (*left*). Side view of kiln; it is made of ordinary bricks and no cement.

FIG. 47 (*centre*). Inside of kiln; it is lit from the top.
FIG. 48 (*right*). The first layer of bricks in the kiln.

sawdust kiln had created a desire for a more complex model.

Glass

At the end of the autumn term the teacher discussed with the children which of the materials locally produced they should study next term. Some children thought that coal would be interesting, but the mine was some miles away and this seemed a disadvantage. Then others urged that it should be glass, since many of their parents worked in the local glassworks.

During the Christmas vacation the teacher

1 made contact with the local glassworks and borrowed a set of glass blower's tools;
2 wrote to a number of glass firms situated further afield and asked for literature and samples;
3 gathered a comprehensive selection of books about glass from the Schools Section of the L.E.A. library service;
4 visited a wholesale bookseller and selected books that he considered would be useful. (The L.E.A. arranges for teachers to visit this wholesaler and make personal selections of books, and so keep the number chosen from catalogues to a minimum.)

At the start of the new term when the teacher asked his class what they wanted to know about glass there was a flow of questions (listed in Appendix 1 to this classroom example).

The work of the previous term had developed from an early visit to the brickworks. The teacher asked if there was any other way of answering their questions. The suggestion was made that glass firms might supply information from which answers could be drawn, and he agreed to the new approach. He gave the children a copy of the trades edition of the local telephone directory. This contained a list of firms dealing in glass and the children were soon busily engaged in writing to them. Most replied, giving:

1 The addresses of the glass manufacturers with whom the wholesalers dealt.

2 The address of the Glass Manufacturers' Federation who in turn sent literature and a list of United Kingdom glass makers.

3 Samples of different types of glass, sets of ophthalmic and optical glass blanks.

4 Leaflets, brochures, catalogues, charts.

5 Facts that answered some of the initial problems posed, such as,

'What is glass made of?' (Answer, sand, soda ash, and limestone.)

'What do you put in to make glass coloured?' (Metallic oxides.)

'How hot does the liquid get?' (Approximately 1,400°C.)

The outgoing letters showed a marked improvement upon those written the previous term. They showed more confidence on the part of the writers and because of this their tone was in most cases more friendly and less formal than before. Some apologised for the inconvenience they were causing, others expressed thanks in anticipation. Each reply was also promptly acknowledged.

The trades edition of the telephone directory was brought into use again and requests for information went out to plastic firms. The manufacturers of plastics proved equally cooperative, and Lynn received from one firm a collection of pamphlets and a large box of plastic containers, skittles, balls, and toys.

With the specialized literature now in the classrooms and the offerings from commercial sources circulating, the children were soon engaged in answering their own questions and also preparing themselves for the visit to the local glassworks. Everyone was now making 'rough' drafts of his work and rewriting to give a neat, finished copy; the booklets prepared were of a much higher standard than those produced three months earlier. The quality of the language was greatly improved, the work was neatly set out, and more pride was being taken in the preparatory work.

Out of the thirty-five children it was found that only three were copying directly from textbooks. These three were among the slowest learners and they were encouraged, not admonished, to try and write 'in their own words'.

Most of the pupils soon met the more common technical terms of glass making and struggled with new words such as *lehr* and *annealing*. But the glass blower's instruments were proving useful. The punty rod was there, so were the blowpipe and shears. Operations they expected to meet in the glassworks were dramatized in the classroom. Every child had the chance to play with, examine, and talk about the glass blower's tools before the visit.

For a day before the outing the children were keyed up with excitement and expectancy. This was no ordinary visit, for they would be meeting relations and neighbours. The visit lived up to their expectations, and inside the entrance gate where workers were clocking in and out there was a number of parents waiting to welcome the class. Rita's father acted as one of the guides and held the attention of his group throughout.

In the mixing plant the sand seemed attractive and when Pauline asked where it came from and was told that it was silver sand from Holland she remarked, 'I thought it didn't come from round here, it's too white.' But the guide added that the silver sand had been cleaned and if 'ours' was treated similarly it would probably look the same. Also in this plant the red lead was noted and this looked dangerous and exciting.

When seeing the clay pots being made Maureen asked: 'Is the reason that these works are here because there is clay, coal, and sand here?'

The glass blowers at work intrigued everyone and when David asked one craftsman how it was done he was invited to try it. David declined the offer, whereupon Philip accepted. This was unexpected and the children were thrilled at this privilege being granted to one of their number. There was, however, some disappointment when Philip failed to produce a 'nice bulb' because he blew with too great a force.

Considerable interest was shown in glass that had been spilled on the floor, had cooled, and resembled 'thick dried tar'. Then there seemed reason for satisfaction when Lynn recognized the lehr before the guide had named it. The 'butcher's shop' fascinated most of the class and many of the girls agreed that it would be a wonderful place to work when they grew up. The women in this section, where the glassware is tested

and rejects are smashed, are not popular with the blowers, who are paid on the number of good bulbs blown.

At the end of the processing and finishing department there was an impressive collection of the items being currently manufactured in the works. Recognizable were cats' eyes, electric bulbs, strip lighting tubes, covers for airport runway lamps, television tubes and valves, vases, drinking glasses, and paper-weights.

A selection of questions put to the guide by one group of seventeen children and some of the answers given are in Appendix 2 to this classroom example.

Next day the children became engaged in one of the following:

1 Writing accounts which on the whole were vivid reminders of the outing and which included much fine detail, accuracy, and colour.
2 Preparing a large scale 'life history of glass' or, as it became in its final highly colourful and realistic form, of glass 'from mixing to finishing'; a part of this is shown in plate 11.
3 Labelling specimens collected on the visit.
4 Using the glass blower's tools to re-enact the operations that had impressed most.

Group investigations quickly grew out of the above and some of these are dealt with below. 'Can we make glass?' was the question most frequently asked and to Alan and Stephen, the most persistent enquirers, was given the task of finding out.

These two took over the seven raw materials (sand, magnesite, syenite, limespar, boric acid, alkali, and cullet—broken glass used in a mixture to be melted) that had been brought from the glassworks, the small electric muffle furnace, borrowed from the area's Institute of Education, and the crucibles and tongs lent by a neighbouring secondary modern school. During the following weeks Alan and Stephen mixed the raw materials in varying proportions and made a careful note of the quantity of each (in units of a teaspoon) and the total weight of the mixture (in grams). *The children carrying out the operations that followed were carefully supervised by an informed teacher.* Each mixture was fired to above 1,000°C. Various results were achieved and with the seventh mixture—of a half spoonful of each raw material, fired at the furnace's maximum temperature—a specimen of blue coloured glass was produced.

Soon the properties of glass and plastics were being compared. Mazorah and Theresa wanted to know 'which will scratch more easily, glass or plastic?' Ten scratching implements were used and these ranged in hardness from a finger nail to Brazilian quartz. These were tried on Perspex, another plastic, and glass. The tests showed that glass had been marked only by quartz, the Perspex bore five marks, while the other plastic had been very soft.

When Maureen asked, 'Which is best, glass or plastic?' she was joined by Pauline and they proceeded to find the effect of heat on small pieces of different plastics and glass. A large wax candle was used to provide a flame and this was sufficient to furnish an interesting set of results.

The glass with the mesh in it was looked upon as much stronger than other samples so that when David and Christopher asked whether they could test the different pieces of glass to see how strong they were, they were encouraged by the teacher to devise a method of doing so. They built a 'butcher's frame' of balsa wood in which weights could be dropped, and tested a number of samples. Figure 49 shows how it was made. If the walls had been enclosed in plywood, the danger of flying splinters would have been reduced.

Every piece of glass tested was eventually broken and the results ranged from breaks by 1 oz. dropped from 1 ft. to 11 oz. falling from 3 ft. Makers of the wired samples claimed that if accidental breakage of this type of glass occurred the wire mesh would hold the fragments together. David and Christopher did not find this to be so, for the wire had snapped in each case.

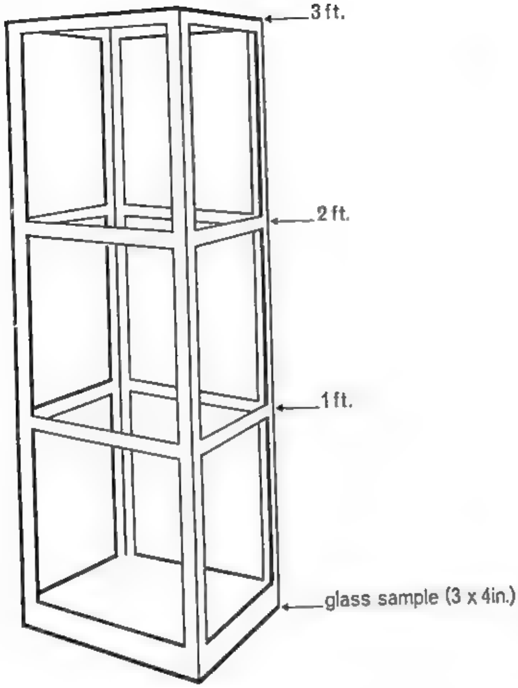


FIG. 49. A 'butcher's' frame to test the strength of glass.

Some of the class tried to make periscopes, and a few successful models were constructed. The teacher was uncertain how this arose but it seemed unlikely that it stemmed from a textbook. A few lenses received from a glass maker were supplemented with spectacle glasses brought in by the class and a range of lenses borrowed from the neighbouring secondary school. The lenses were placed in cardboard tubes to make simple telescopes. The telescope makers were excited with the results but a little dismayed to find the images upside down. This was however rectified when Lawrence accidentally made his image appear the right way up.

Michael had read about the spectrum and used glass blocks and various light sources—including the school film strip projector—to produce spectra of different brightnesses.

Philip and Kevin tried different lenses as burning glasses. When they were trying this Theresa volunteered the story of Archimedes and the burning of the Roman fleet. It had appeared in a number of last year's *Science Club Junior*.*

Making telescopes led to discussions about astronomy and space flight and when the teacher introduced books on astronomy they were in immediate demand. This prompted him to arrange two voluntary visits to a local observatory. On the first evening the sky was overcast but the children were shown lantern slides by the astronomer and in the discussions which followed his talk, both he and the teacher found the children knowledgeable and extremely interested. On the second visit to the observatory they found the telescope—valued at £900—in use and they viewed the Moon and Jupiter. Some saw three of Jupiter's satellites whilst others saw a fourth satellite appear. On each occasion over two-thirds of the class visited the observatory.

Stephen and Alan, when making glass, had made considerable use of the microscope to see what the chemicals they were using 'really looked like'. Others in the class did likewise and soon the raw materials were being mixed in water to see the effects.

After Lynn had discovered that good glass rubbings could be made from a box of samples sent by one glass maker most of the class tried it and there was soon a colourful show of rubbings. Fortunately, Lynn's

* The teacher told the class the opinion of two authorities on this:

'Certainly all the legends of Archimedes' war machines must have had some foundation. . . . He was a relation of Hiero II, the last tyrant of Syracuse, and took a large part in the defence of that city against the Romans. He was killed, while working out a problem by a Roman soldier.'

Bernal, J. D. (1965) *Science in History*. Watts.

'It is said that he made concave mirrors, with which he set fire to the Roman ships by concentrating the sun's rays on them; but this story is doubtful.'

Hull, L. W. H. (1959), *History and Philosophy of Science*. Longmans, Green.

PLATE 10. Two stages in the children's model of the life history of a brick (p. 152).

PLATE 11. A stage in the children's portrayal of the life history of glass (p. 159).

PLATE 12. The finishing touches took three weeks (p. 215).

discovery was made before all the samples of flat glass had been tested in David's and Christopher's butcher's frame.

Finally, should any reader wonder how glass paperweights are made, this account provided by Rita might suffice:

> 'I asked the man how they made paperweights. He said you get a flat piece of glass then you get the odd pieces of coloured glass then shape it into flowers then put some more glass on top and let it set. But they only make them in their spare time.'

Appendix 1

A selection of the questions before the visit to the glassworks

1 What is glass made from?
2 How do you get glass round in shape?
3 How do you get writing on glass?
4 How do you get glass smooth on the edges?
5 How do you get glass into patterns?
6 How do you get pictures and colours into glass?
7 How do you shape glass?
8 How do you make paperweights?
9 How do you make different kinds of glass?
10 Why do you use glass rather than plastics?
11 How do you put shapes on glass?
12 How do they cut glass?
13 How do they put things in glass without a cut showing?
14 What kind of glass is used for car windscreens?
15 Are there such things as glass hinges?
16 What do you put in to make glass coloured?
17 Why does glass break?
18 What do you add to make glass waterproof? (Was Maureen, who asked this, thinking of clay not being waterproofed until it is glazed?)

19 How do they get glass into coloured marbles?
20 How do they make glass with coloured lines on it?
21 What is the man called who blows the glass?
22 How many kinds of glass are there?
23 How do they make glasses (meaning spectacles)?
24 Why is glass sharp?
25 Why do we have glass windows?
26 How do you make glass magnify?
27 How many times does glass go into the furnace?
28 What tools do you use in making glass?
29 How do they make toys for Christmas trees?
30 How long does molten glass take to harden?
31 How hot does the liquid glass get?
32 Who made up the idea of glass?
33 Are milk bottles made in glassworks?
34 How long does it take to make glass?
35 Is glass hard to make?
36 At one time was glass made by hand?

Appendix 2

A selection of questions asked by one group (of 17 children) and of answers given, during the visit to the glassworks

1 Why do we need glasses?
2 What do you call those?
A. Small barrows for glass mixtures.
3 Why do you have kilns?
4 How many different kinds of glass do you make?
A. Lime soda, alumino silicate, and various coloured glasses such as red, orange, yellow, blue, and green.
5 Is that a punty rod?
A. Yes.

6 Why does he fan the tubing as it is being drawn out?

7 How hot is it (the glass in the furnace)?
A. About 1,480°C.

8 How many tubes can be blown in an hour?

9 Is that drawing out glass?

10 Is it hard to blow?

11 Why do they have water to put the mould in?

12 Is that the lehr machine?
A. Yes.

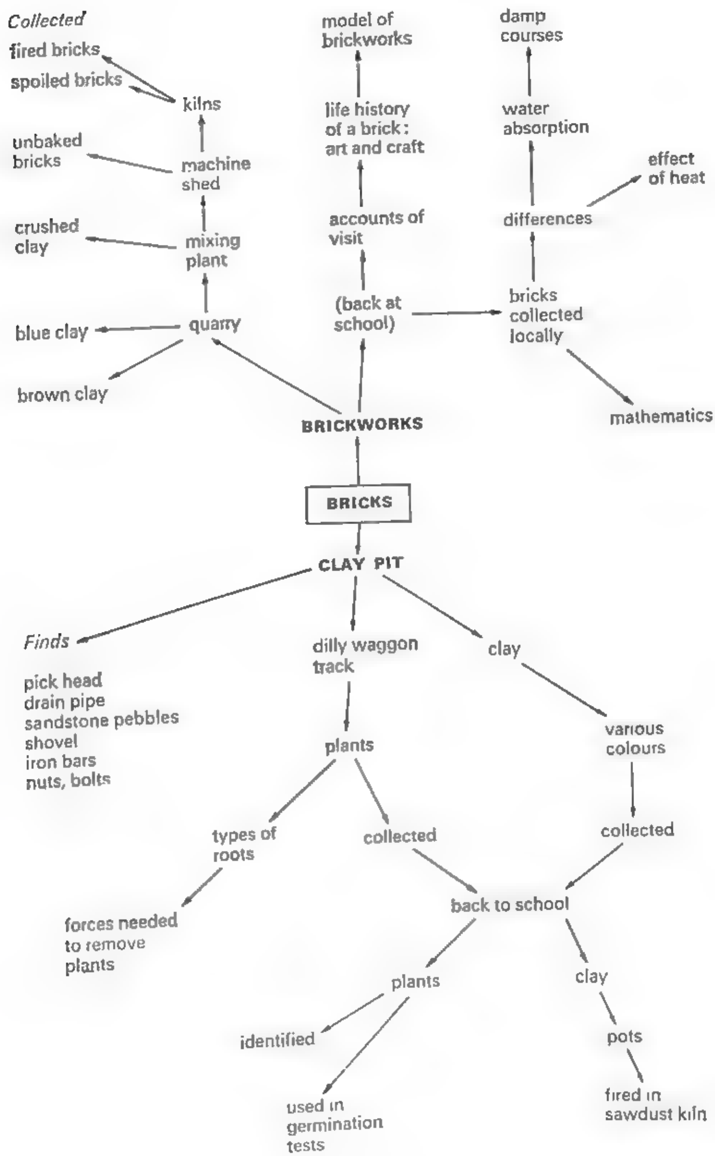
13 How do you make paperweights?

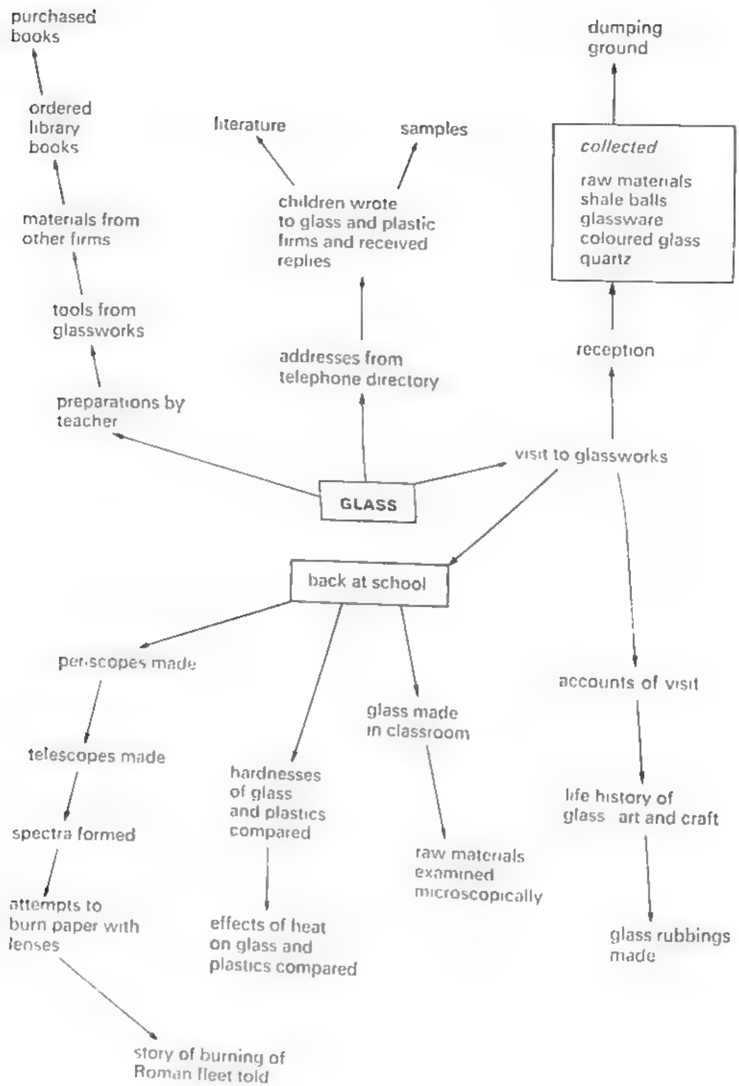
14 Why do you use red lead?
A. To make crystal glass.

15 How tall is the cone?
A. 130 ft.

16 Why is it called the 'butcher's shop'?

Of the other questions asked, and there were many, most were asking for confirmation of something which had already been discovered.


Collected
fired bricks
spoiled bricks
kilns
unbaked bricks
machine shed
crushed clay
mixing plant
blue clay
quarry
brown clay
model of brickworks
life history of a brick: art and craft
accounts of visit
(back at school)
damp courses
water absorption
effect of heat
differences
bricks collected locally
mathematics
BRICKWORKS
BRICKS
CLAY PIT
Finds
pick head
drain pipe
sandstone pebbles
shovel
iron bars
nuts, bolts
dilly waggon track
clay
plants
various colours
types of roots
collected
collected
forces needed to remove plants
back to school
plants
clay
identified
pots
used in germination tests
fired in sawdust kiln


purchased books
ordered library books
materials from other firms
tools from glassworks
preparations by teacher
literature
samples
children wrote to glass and plastic firms and received replies
addresses from telephone directory
dumping ground
collected
raw materials
shale balls
glassware
coloured glass
quartz
reception
visit to glassworks
GLASS
back at school
periscopes made
telescopes made
spectra formed
attempts to burn paper with lenses
story of burning of Roman fleet told
hardnesses of glass and plastics compared
effects of heat on glass and plastics compared
glass made in classroom
raw materials examined microscopically
accounts of visit
life history of glass art and craft
glass rubbings made

27 *Sea-coal for sale, and candles*

Class	**9-11 years. Educationally sub-normal. Home backgrounds of many in class extremely difficult.**
Class number School roll	17 boys 70
Terms	Two autumns
Building	Post-war. First used as an infants' school, then as a school of art, and now for E.S.N. pupils.
Classroom	Adequate facilities. Modern desks with some work tables. Services include a sink.
School environment	Large post-war housing estate on the fringe of a city. Around the building there are a field and playground.
Local setting	North-east England. Large city. Heavy engineering, coal mining, ship building, and light industries.

BEAT THE COLD!

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SEA-COAL

5/– per cwt.

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14 Orchard Avenue, North Shields.

Sea-coal

Advertisements such as these appear regularly in some north-country newspapers and for this teacher were the starting point. Before the advertisements were mentioned in class the teacher made two visits to a beach where sea-coal would be found, and satisfied himself that it was a suitable place for E.S.N. children to visit.

The two advertisements were displayed to the class with the question: 'Which would you buy?'

This created an interest in sea-coal, and the proposal to visit the beach led to further speculation.

Just before the visit the boys asked two questions: 'Will we be going far?' and 'Is it up to Scotland?'

When the class were asked to find a way of measuring the distance and the only

reasonable suggestion was 'to count the milestones', the teacher indicated that there was something in the Bedford van in which they would travel, which might help. This clue was sufficient for Philip to say that the mileometer could be used. Accordingly, he recorded the last two figures it showed before starting, and on arrival at the beach he was able to calculate the distance from school.

The beach, black with coal, was in striking contrast to the pleasure beaches with which these city children were familiar. Three comments expressed their feelings:

'Eh, it's all black.'
'I wouldn't like to plodge [paddle] there.'
'Can I take some home?'

A base was established at the foot of a cliff and the boys were allowed the freedom of the beach. Soon a number were examining a thin black seam near the base of the cliff—which the teacher had noted on an earlier visit—and Billy asked: 'Is this coal?'

The teacher replied that it looked like coal, but how could they find out? The response was: 'Burn it.'

The class had brought two hammers and while two boys chipped at the black rock, the remainder rushed off to collect driftwood. Pieces of the black rock were soon fed on to the blazing wood and although it crackled, it definitely burned. It was coal! The teacher had anticipated this development and, suggesting that the fire might be put to a use, he produced a kettle, water, cocoa, sugar, and beakers from his two large rucksacks. Making their own cocoa was a thrilling experience for these boys.

As they sat around their fire sipping cocoa their teacher produced a large cheese sandwich, and asked everyone to look at the edge of the sandwich and then at the cliff and the outcropping coal. Cheese and coal were related, and no matter where any boy pushed his finger down through the bread it always came to cheese. Thus, a mine sunk anywhere in the fields above the cliff would always come to the 'slice' of coal.

The teacher then thought it would be a good idea to measure the seam, which proved to be four inches thick. Samples were collected and, while this was being done, the boys were asked to gather rocks and lumps of coal of similar sizes. They were to discover that coal was lighter in weight in practically every case.

The class then moved to the beach and found pieces of coal along the tide line. This was sea-coal, but it was a long time before someone asked, 'Does it come out of the sea?'

The teacher thought it might but, if so, how did the coal get into the sea? The men who were collecting coal on the beach might know the answer, and when the boys asked them, three views were forthcoming:

'It is washed off ships.' [The speaker meant, specifically, colliers bound for the Thames.]
'It comes from colliery spoil heaps.'
'It is washed off the sea bed.'

The boys were ready to accept the three explanations, but the teacher thought the last seemed the most likely. Would it not be a good idea to contact the colliery manager of the nearest mine and ask his opinion?

He encouraged the boys to notice similarities and differences when comparing cliff coal and sea-coal. Both types were black, shiny, and light. The differences—more difficult to detect—escaped them until Billy was asked to close his eyes while holding a piece of mined coal in one hand and a sea-coal pebble in the other. Billy's sense of touch told him at once that the cliff coal was rough and the beach coal was smooth. They immediately examined the sea-coal they had collected and none of it had sharp edges. After each boy had put his sea-coal in one rucksack, the teacher said further collecting should be restricted to pieces of brick, bottle tops, glass specimens, and stones. In collecting rocks and pebbles, the heaviest, lightest, roughest, smoothest, and flattest were sought.

Before leaving, two more exciting finds were made. Lying vertically in the face of the

cliff was an enormous fossil tree*. This had been extremely well preserved, and the boys enjoyed feeling the bark patterns. Nearby on the cliff face the class was attracted by a shelf of hard rock which had been left when softer strata above and below had been removed.

In the classroom, the boys eagerly unpacked the beach finds, and an exercise that immediately appealed to most of the class was to arrange the pieces of brick in order, from the most complete specimen to the most rounded pebble. Some boys were unable to accomplish this, but the two sets of eroded specimens were later displayed to illustrate the formation of sand.

Another class activity was the composition of a letter—written by the teacher—to the colliery manager. His reply said that the sea-coal came from the sea bed, and one group proceeded to illustrate this by means of a plaster model.

The rocks and flints were distributed among groups and in almost every case the specimens were subjected to hammering. Sandstones yielded sand and flints were split to provide sharp edges. One group used the sand they had made for making sandpaper. Another found that a loaded pail gave enough pressure to bond the sand together to recreate a sandstone. The razor-edged flints were used for cutting wood and sharpening pencils.

All that had been collected on the beach was labelled and placed on display with items produced in the classroom. Prominent among the beach finds were the tree fossils and samples of coal extracted from the cliff. More meaning was given to the display by a collection of photographs taken by the teacher during the visit.

The investigation ended with a class activity that proved most popular. A large amount of sea-coal remained untouched. What should be done with it? Rather than make cocoa for a second time, the class wanted to bake something. Next day the teacher produced a dead pigeon that he had bought and soon sea-coal was blazing in the playground, while the bird, wrapped in aluminium foil and clay, was roasted in the fire.

The event was recorded by Robert who reported in that month's issue of the school newspaper:

> 'Mr. Pearson brought a dead pigeon from the market. We made a fire with sticks and paper and sea-coal outside the classroom window. We wrapped the pigeon in clay and tin foil to stop it burning, and then we toasted it in the fire. It took over an hour to cook and then we ate it. Everyone got a piece. It had a nice taste.'

Candles

Throughout the following terms, the teacher continued this same approach to learning. Of course, the composition of the class changed so that three terms later only about half the original 'sea-coal class' remained. This newly composed group decided to investigate candles.

This started when Colin was working with Plasticine during an art period and made a model candle. He was disappointed to find that it would not light and when he compared it with a real one saw that his candle lacked a wick. 'Me wants a straw,' said Colin. Although eleven, Colin still worded his requirements in this way. He then remodelled his Plasticine round a drinking straw and when it was lit he watched the straw burn down to the Plasticine.

The teacher then asked Colin to re-make his candle and set it beside the real one. The class was gathered round and Colin lit the two candles. His soon went out but the other burned on. 'Why has Colin's candle gone out?' queried the teacher. The response was immediate:

> 'It's not a real candle.'
> 'It hasn't a proper wick.'

The boys thought that twine could be used to

* The teacher photographed this and passed a copy of the print to a university's geology department. The following week members of the department visited the beach.

make wicks. Colin made another small Plasticine candle with a twine wick and John, using some of the soft wax from the burning candle, fashioned a small wax candle around a piece of twine. The Plasticine candle behaved as before, but John's candle burned well, and prompted him to say, 'The candle grease burns but the Plasticine doesn't.'

The boys were asked what happened when the grease 'got hot' and it seemed clear to them it melted. They were keen to dip spent matches into the pool of liquid wax surrounding the wick and they could see that Colin's candle had no such pool because the Plasticine did not melt. When the children were asked to find other substances that melt on heating, they suggested butter, dripping, and ice.

One group showed that it was possible to boil water in a tin lid over a candle. But when their teacher remarked that we eat fats, because we can 'burn them up inside' and they help to keep us warm, the boys found it difficult to comprehend. It seemed incredible that the Eskimo will eat a tallow candle for the reason stated. Was it possible to give them some idea of the relationship between combustion and metabolism even though they did not adequately understand either? When asked which fats we eat to keep us warm the replies were, 'butter, dripping, and margarine.' The class was left with a further question, 'Can you make candles out of those?'

Next day George arrived at school with a butter candle and was keen to show that it worked. Others had brought pieces of candles of different sizes and one boy had a night light. 'Will a short fat candle burn longer than one of the tall thin ones?' seemed an obvious question to the teacher. This immediately caused a difference of opinion. They burned the candles, kept a careful check, and recorded their finds. Soon it was obvious to them that a thin candle burns down faster than a thick one and that candles of similar diameter burn at about the same rate or 'keep level with each other'.

To sustain interest in measuring the passage of time the work was extended to make a candle clock. This helped some children to grasp the idea of 'half past' when they could see the burning candle standing half way between the two above and the three below. Previously they had found it difficult to realize that the six on a clock face is 'half way round'.

When one candle went out Billy wanted to use the wax to make a new candle. He did this and in due course made another smaller candle from the wax left over. What had been a tall candle was reduced to a few drops of wax. Where had the candle gone? The teacher produced the tin lid in which the water had been previously boiled. It was examined and it was not long before fingers had found the soot. Thus a burning candle will give us light, heat, and soot. The soot appealed to the boys most and they burned more candles to make some more. White plates provided ideal surfaces on which to collect films of soot. A layer of it on a plate gave a novel surface on which to draw with sticks.

In an attempt to give meaning to the heat-light relationship the teacher heated a large nail in the classroom stove until it was red hot. When the teacher carried it with tongs into a dark store room the nail provided enough light to read by. *Note:* When carrying out an operation like this, a teacher must take strict safety precautions.

The class followed up this experiment by examining the filaments in electric lamps.

The teacher next asked for an account of how a table jelly is made, and was told that when the jelly sets it takes the shape of the basin into which it has been poured. He asked, could we make a candle in a mould? What could we use to make a mould?' Soon a group was busy working with the familiar materials of clay, Plasticine, and papier-mâché. The clay and Plasticine were both used to make decorative moulds.

The teacher thought that beeswax from the class hive could be used to show the old fashioned method of candle dipping. Wax, broken from old frames, was melted in a tin in hot water. A wick was tied to a pencil

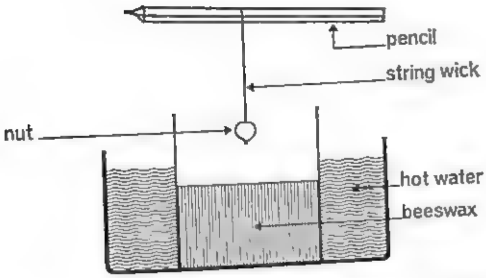


FIG. 50. The teacher demonstrated candle dipping.

but the end of the string would not sink into the liquid. 'What can we do to sink it?' asked the teacher. 'Tie a bead on the end,' answered Joe. Someone produced a small nut to act as a sinker. This took the string down for its first dip. As it came up the boys were excited to see what one of them immediately described as a 'skinny candle'. John dipped it again and everyone watched it grow fatter until after its twenty-first dip it was judged 'a good candle'. Figure 50 shows the apparatus used.

Some wax had spilled into the dish of water and Billy noted that it floated. The teacher offered them other fats and oils to test.

When one of the beeswax candles was lit, Joe described it as a 'poor light'. The teacher asked where they might test candles to see if they would provide a strong light in the dark. Various suggestions were made and it seemed that the stage in the school hall would be a good place to try them out. On the blacked-out stage one candle provided poor illumination. A book could be read if it was held close to the candle but the corners of the stage were very dark. Carrying the candle one boy pretended to climb upstairs to bed and the rest of the class seemed impressed by the weak but strange shadow thrown on the stage wall. Was this ghost-like? asked the teacher. Had the candle played a part in some ghost stories and folk tales?

But the boys were there to test 'candle strengths' and a second candle was lit. With two flames, the increase in light was appreciated. A third and fourth were added and each one increased the light intensity. The class were in fact comparing light intensity in simple terms.

Back in the classroom it was agreed that light from a single candle was a 'poor light'. 'What other disadvantages have candles?' asked the teacher. The boys suggested:

1 Smell.
2 Danger of fire.
3 Smoke and soot.
4 Grease dropped.
5 Affected by wind (easily blown out, unsteady flame).
6 Time taken to light up.

The last disadvantage caused much fun and amusement. A stopwatch was used to find the time for each boy to get a light from a candle and compare it with the time needed to switch on an electric light. In some cases the candle took as much as 15 seconds longer and there was general agreement that modern methods of 'lighting' make life easier.

The shadows thrown on the stage wall had, however, not been forgotten and the classroom store—a small darkroom—seemed an ideal place to make shadows. Candles were used to throw shadows, and some good silhouettes—of various objects and heads—were drawn on

FIG. 51. Painting of silhouette thrown up by candle-light.

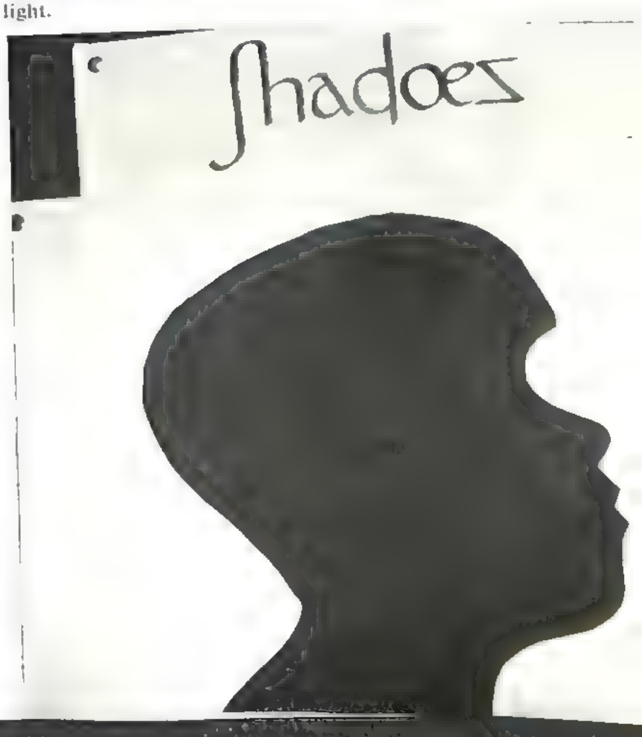


FIG. 52. Hallowe'en lantern.

white (drawing paper) screens. One can be seen in figure 51. The painting of 'shadows' was extremely popular and so was simple shadow play using a candlelight source and white screens.

At the time of Hallowe'en there was great activity in hollowing out turnips to make turnip lanterns and these were illuminated, as usual, by candles. Figure 52 shows one of them.

Some two weeks after work with candles had ceased one boy found in a book a drawing of an ancient oil lamp, and wanted to know how it worked. A discussion followed and the lamp that was made consisted of an eggshell containing olive oil and a string wick. It is illustrated in figure 53. It provided a good light and a bad smell!

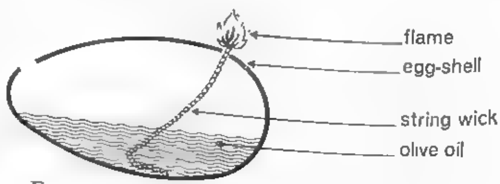
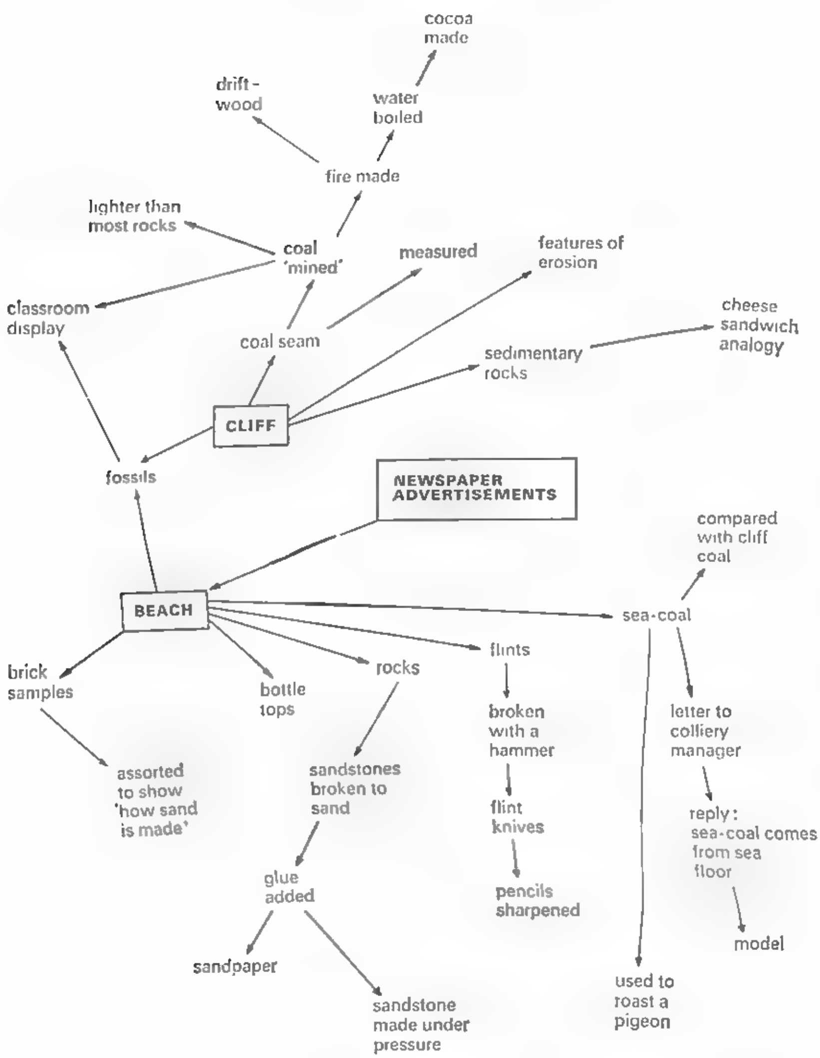
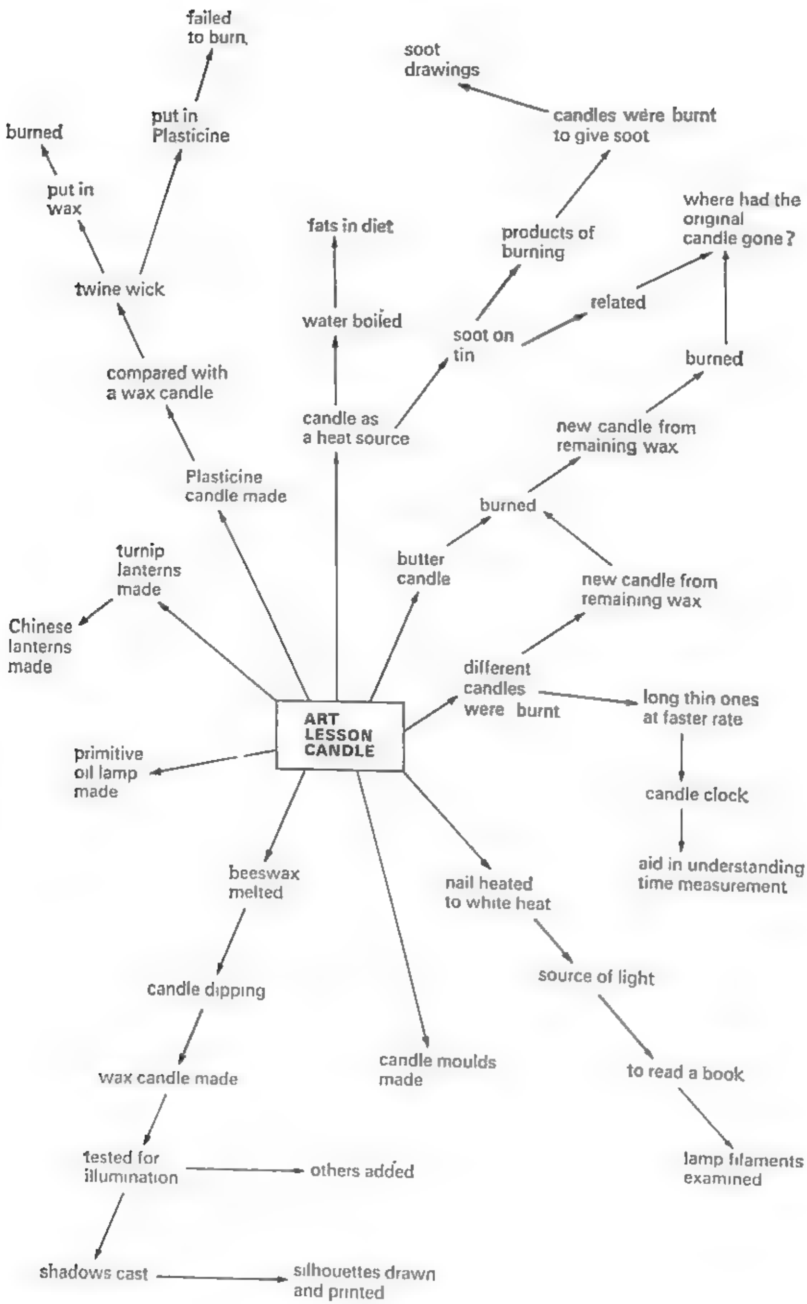


FIG. 53. The boys made a primitive oil lamp.


cocoa made
drift-wood
water boiled
fire made
lighter than most rocks
coal 'mined'
measured
features of erosion
classroom display
coal seam
cheese sandwich analogy
sedimentary rocks
CLIFF
fossils
NEWSPAPER ADVERTISEMENTS
compared with cliff coal
BEACH
sea-coal
brick samples
bottle tops
rocks
flints
broken with a hammer
letter to colliery manager
assorted to show 'how sand is made'
sandstones broken to sand
flint knives
reply: sea-coal comes from sea floor
glue added
pencils sharpened
model
sandpaper
sandstone made under pressure
used to roast a pigeon



ART LESSON CANDLE
failed to burn
put in Plasticine
burned
put in wax
twine wick
compared with a wax candle
Plasticine candle made
soot drawings
candles were burnt to give soot
products of burning
where had the original candle gone?
related
soot on tin
fats in diet
water boiled
candle as a heat source
burned
new candle from remaining wax
burned
butter candle
new candle from remaining wax
different candles were burnt
long thin ones at faster rate
candle clock
aid in understanding time measurement
turnip lanterns made
Chinese lanterns made
primitive oil lamp made
beeswax melted
candle dipping
wax candle made
tested for illumination
others added
shadows cast
silhouettes drawn and printed
candle moulds made
nail heated to white heat
source of light
to read a book
lamp filaments examined

28 *A weather saying, birds, and a woollen mill*

Class	9-11 years. Full range of ability
Class number School roll	34 boys and girls 84
Terms	Autumn, spring, and summer
Building	Attractive. Built in 1932 as an all-age school. Now, without seniors, there are spare classrooms.
Classroom	Light and airy. A former housecraft room with a generous floor area, storage space, and services.
School environment	Within the grounds there are a field and paved area. Nearby is the river Rede, and the surrounding pastures are grazed by sheep and cattle.
Local setting	North-east England. The school is situated a mile beyond a small upland village. The scene is one of hills, moorland, and state forests.

Rose hips*

It was suggested to the teacher that the class might visit some acid moorlands and a sheep farm where peat is still burned as a household fuel, where there would be much to investigate. But the teacher preferred to restrict the work of the first term to the more immediate vicinity of the school. Weather study appealed, and as a starting point he asked the children to consider whether this old Scottish weather saying was true:

'A haw year
A snaw year.'

Geographically, the school is close enough to the Scottish border for the saying to be understood and expressed locally, and indeed, to be accepted as reliable. This final point might stress the value of putting to the test weather sayings, superstitions, folklore, magic, and advertisements when appropriate.

The class was immediately interested in the saying and in the possibility of its having a doubtful value. Had anyone proved its worth? Discussion made it clear that a count of haws over a large area would take a long time and be fraught with difficulties. Soon the discussion switched to rose hips, and

* This example is chosen because, as a topic, it proves to be an interesting approach to weather study and because it is a good example of the way in which the original question (in this case, asked by the teacher) is abandoned at an early stage as other and more pressing questions are asked.

although hips and haws are different it seemed possible that there might be some relationship between the hip harvest of autumn and the snows of the following seasons. Rose hips had some meaning for the children. At that very moment, there was a chart in the corridor outside recording those hips that they had collected. Had not ten-year-old Bruce already picked 32 lb.—at 5d per lb.—this autumn?

The children knew that the hips they gathered were collected each Monday morning and then made into the rose hip syrup known to them from their earliest days, which they still received regularly on milk puddings in the school canteen.

The teacher himself had searched the literature to prepare for the development he anticipated, but the only useful reference to rose hips that he found was in *British Herbs** This describes the wartime manufacture of rose hip syrup for a nation, and the class was astounded to learn that something so familiar had such exciting origins. Vitamin C content was mentioned without elaboration, but with the thought that questions might arise.

The response was immediate, with the realization that there was much they did not know about this commonplace fruit, and below are the questions that followed:

Why are the best ones at the top of the bush?
How do rose hips grow?
Which part has Vitamin C in it?
Do they make syrup with machines?
Why are there leaves and prickles on the bushes?
Do rose hips grow in other countries?
How do their seeds spread?
How do they turn from green to red?
If picked when wet, why do hips go mouldy?
Can you eat rose hips by themselves?
Where do they make the syrup?
Who found out about the syrup?
Why are the seeds white?

* Ranson, F. (1949) Pelican Book, *British Herbs*. Penguin Books.

FIG. 54. Straining syrup.

How do birds know about seeds inside?
Are there nests in rose hip bushes?
Why do birds eat them?
When are they ripest?
Why is it sticky inside?
How many seeds are there in a hip?
Do the leaves change colour? When?
Are there uses for rose hips other than making syrup?
Where are the seeds?

If the final question should seem out of context, it is interesting that it was asked by Patrick who had recently arrived from an industrial area.

The teacher was overwhelmed by the flow of questions and wrote: 'This torrent I simply record. I didn't attempt to cope, but merely encouraged. Answers to some we will attempt later.'

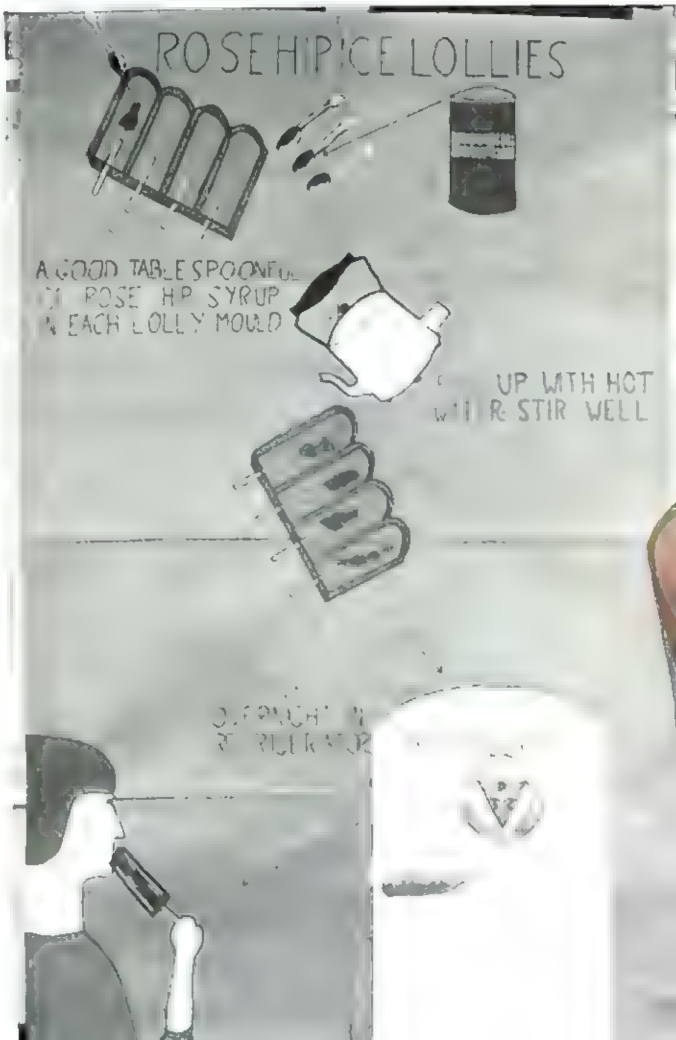
The next day several children brought hips, but preferred pennies to science. Lucille, however, offered some hips for experimentation, and with two each, the class counted all the seeds. There were on average 39 seeds per hip. This was duly recorded and placed on display by two boys acting on their own.

A partial answer to another of the questions came by accident. As a girl, Kathleen's mother used rose hip seeds as itching powder. Paul put this to the test by doing it to himself at playtime. He reported that he wished he hadn't.

The next step in the investigation was determined when the girls asked if they could make rose hip jelly (not syrup), and the teacher readily agreed, provided that enough hips were forthcoming. The request was made on a Friday and on the Monday morning rose hips arrived in quantity.

Two girls topped and tailed a panful and were then advised by the school cook to wait until the next day so that a full day's boiling could be given. 'Boiling day' arrived amidst great excitement, but before boiling began, the class were brought together to remind them of the weather saying, and the children decided that if 'our version of the saying' was to be tested quantitatively, rose hip returns from other schools for 1961, 1962, and 1963 were required. A group also compiled a questionnaire and sent this to a commercial firm which processes rose hips. This is shown in Appendix 2 page 178. Thus, group activities commenced with a general interest being directed towards the 'boiling group', seen at work in figure 54. Soon after boiling had started, someone asked, 'How many rose hips have been put in the pan?' and someone else wondered, 'How could we estimate this?' Bruce quickly found an answer: 'Refill the pan to the present marked level and count the berries used.' After overnight straining, the group added 1 lb. sugar to a pint of juice, and after further

FIG. 55. How to make ice lollies with rose hip syrup.



boiling it failed to turn into jelly. The school cook wanted to add some lemon 'stiffening', but the group and class were suddenly thrilled with the syrup which they now preferred to jelly. The syrup was tasted by everyone and all agreed that it was sweet, 'syrupy', and definitely 'rose-hippy'.

A request immediately went to the cook to use their syrup on the next milk pudding, and the following day sago was provided for sweet. There was sufficient syrup for all and there was general agreement that 'ours was sweeter, more concentrated, and better than the commercial product.'

Soon the questionnaire returned from the manufacturer's laboratories, but although some useful information was provided in a covering letter, the firm would not divulge quantities of hips received or amounts of syrup produced, as asked. In spite of this, the questionnaire was responsible for a new development, for Lucille, indignant at the manufacturer's attitude, thought that one of the few answers they had given could be proved wrong. The question was No. 5, 'What other products can be produced from rose hips besides syrup?' The terse answer had been 'none'. Lucille contended that this was wrong if rose hip ice lollies could be made.

A new group began production of a new stock of syrup and noted that in 21 lb. there were 682 hips. From this, $1\frac{1}{2}$ pints of juice were recovered and $1\frac{1}{2}$ lb. of sugar were added. The children used the syrup to flavour ice lollies (and did a painting of their method, as you can see in figure 55), toffee, and jelly, and each was voted an outstanding success. By then, the work was arousing interest throughout the school and the surrounding district. The infants' teacher had been prompted to make a tray of rose hip toffee at home, and relatives were searching for long-forgotten rose hip recipes.

Recording was varied and undertaken with enthusiasm. Rose hip returns from other schools, summarized in Appendix 1, page 178, were appearing daily and the children decided that these could best be displayed on a map of Northumberland. Each child produced his own rose hip story (in a booklet), and it was refreshing to note that one group record carried as its title, 'Hip, Hip, Hooray!'

There was also reason for satisfaction in one minor development. The teacher of the lower juniors had offered to have a sample of the school syrup analysed, and when the

FIG. 56. The children's frieze of their bird table.

analyst's report, given in Appendix 3, page 178, was received, the Vitamin C content was found to compare favourably with that of commercial syrup. But what impressed the children more was the prowess of a Cumberland school which, as recorded in Appendix 1, collected literally tons of rose hips annually.

Further possible investigations into rose hips were not encouraged at this point, for when an earlier question relating to birds eating hips was restated by the teacher, it started a flow of questions related to bird study. Many of the questions could not be answered through the children's own investigations. An example is, 'Why do birds not have big ears?' The teacher therefore selected one which he thought would lead to first-hand observation and experiment: 'Why do some birds eat berries and some eat bread?'

Discussion led to the making of a bird table to fit on the ledge of a classroom window. The children brought food from home but there were too many children to observe one bird table so five groups were formed. Each group took a large drawing board and placed it in the school grounds where it could easily be watched. On the last day of November there was a hard frost, the birds fed readily, and there was great activity at the 'feeding boards'. This led to:

1 A number of children drawing birds and making a large picture frieze of a bird table. This is shown in figure 56.
2 Most children making notes.
3 Many designing bird tables with tin lids nailed to the boards for holding various foods.

Excitement mounted when ten starlings descended upon a table and quickly cleared it of food. This happened when the 'bird tables' were being used to test the appeal—in terms of hardness, softness, colour, etc.—of various foods. Further ideas, in question form, were as follows:

PAUL: What would happen if we put bread inside a rose hip?
BRUCE: How do tits know there is food inside a monkey nut? Could we seal the nuts in paper shells or in tin foil?
ANNE: What would happen if we dye a rose hip? Would it be eaten?
LUCILLE: Freeze hard ice around food. For example, around a hip. Can they get it?
OTHERS: Put some hip seeds in a monkey nut shell. What happens?
OTHERS AGAIN: Drop monkey nuts into a water cup. Will they be recovered?

To some extent, the children followed up these suggested starts, but the monkey nut experiment ended prematurely when the nut supply was exhausted. The situation was eased, however, when Bruce found a large bag of rose hips that his mother had stored in her larder. All bird tables turned at once to rose hip work, only to find that the birds showed no interest in the rose hips provided.

Although during the ten-week period some evidence had been gathered which might indicate whether or not

'A haw year
A snaw year'.

was true, the term ended without any definite conclusion being reached. Clearly, the teacher could, had he wished, have led his class to a point from which the validity of the weather saying could have been viewed. Wisely, after a start that had not been of the children's choice, he encouraged the children to follow their own lines of enquiry.

The routes they followed from questions to answers were taken with tremendous enthusiasm. These top juniors were excited to find themselves in the role of discoverer, and were constantly willing to talk about their findings or the work in hand. It was also pleasing to note how involved the parents became and the part played by other schools.

No insurmountable obstacles arose during the term, and there was a minor setback only when the supply of nuts was exhausted. Enthusiasm lost at one point can, however, usually be replaced quickly by some new and equally fascinating interest.

Appendix 1

Amounts of rose hips collected by other schools 1961-64

School	*Rose hips collected, in pounds*			
	1961	*1962*	*1963*	*1964**
Scremerston C.P.	'Fair'	'Good'	'Poor'	'Record'
Tillmouth C.P.	1,044	731	379	832
Kirknewton C.P.	329	1,317	755	—
Glanton C.P.	—	—	136	306
Ellington C.P.	1,091	390	241	800
Lynemouth C.P	1,350	1,200	750	1,094
Red Row C.P.				
Cambo C.P.	—	—	170	350
Wark C.P.	1,044	731	379	832
Whalton C.P.	712	534	209	157
Chollerton C.P.	1,355	2,015	1,367	2,042
Slaley C.P.	304	178	253	589
Allendale C.S.				
Eden C.S., Carlisle	13,244	19,694	13,244	30,000

* 'To date'. That is, these are incomplete returns.

Appendix 2

The children's questionnaire to a manufacturer

1. What were the amounts of rose hips used in 1961, 1962, and 1963?
   1961 .. ..
   1962 .. ..
   1963 .. ..
2. What were the amounts collected from the schools?
   1961 .. ..
   1962 .. ..
   1963 .. ..
3. What are the best areas of Great Britain?
4. What is the harvest period of rose hips in this country?
5. What other products can be produced from rose hips besides syrup?
6. Output of syrup for 1961, 1962, and 1963?
   1961 .. ..
   1962 .. ..
   1963 .. ..

Appendix 3

Analyst's report on the school rose hip syrup

E. Fogden, B.Sc., F.R.I.C.
Public Analyst & Consulting Chemist

16 Hamilton Road
Sherwood
Nottingham
27th October 1964

Mr. C. R. Mills
City of Nottingham Health Services
50 Shakespeare Street
Nottingham

Dear Mr. Mills:

Rose Hip Syrup

I have examined the sample of Rose Hip Syrup which you left with me on Monday, 26th October, 1964, for the presence of Vitamin C.

I find that Vitamin C is present to the extend of 65 mg. per fluid ounce.

This compares fairly well with products such as . . . where they declare not less than 65 mg. per fl. oz. but which normally contain about 70 mg. per fl. oz.

If the present sample is to be labelled I would suggest declaring 55 mg. per fluid ounce, thus giving a tolerance to allow for storage losses, etc.

Yours sincerely,
(sgd.) E. Fogden

Birds

In the spring term, the bird tables soon became the scene of great activity, and observations were made, counts carried out, and feeding habits studied. What form would

the recording take? The findings from two bird tables were placed in group books. Another group pasted their reports on manilla paper, while the records from the other two groups were stuck on large bird shapes that had been cut from sugar paper. Lucille had been responsible for this attractive form of recording, and an example of her work can be seen in figure 57.

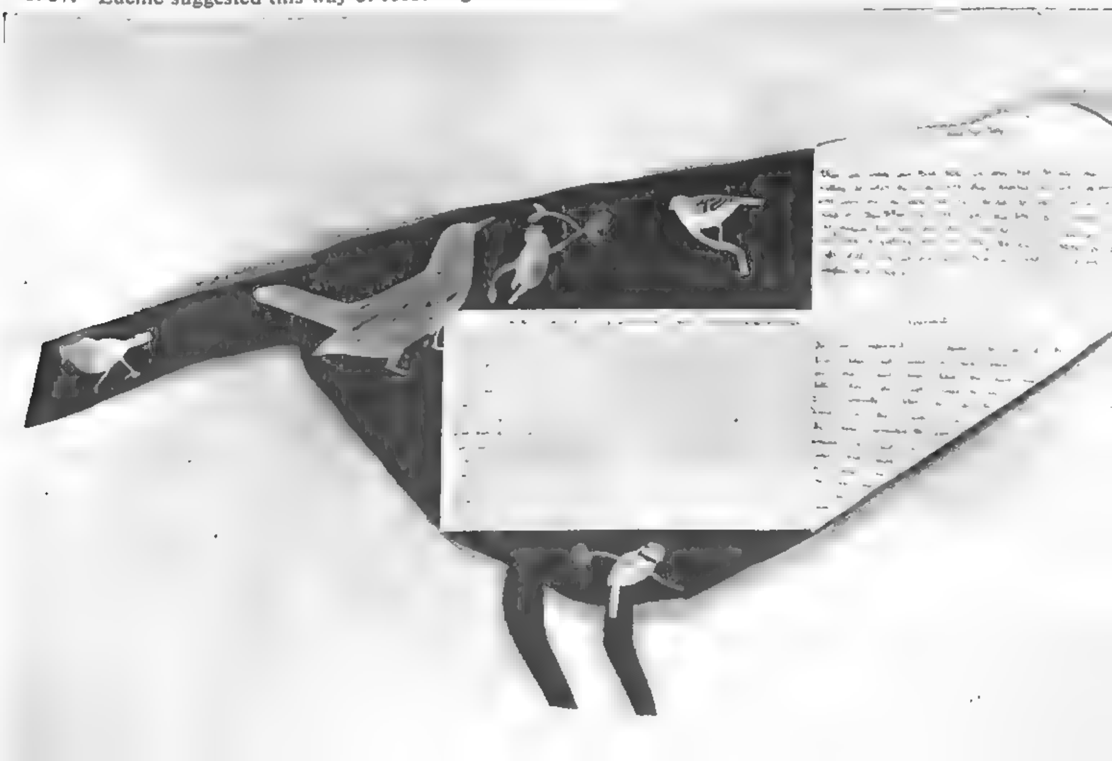
One group extended their recording to making models of birds which had visited their table. The materials utilized were papier mâché, glue, wire, and paints, and some life-like representatives were produced by Brian and Bruce. The making of legs and feet for each model had presented difficulties and nothing better than wire could be found. This led to a consideration of variations in the structure of birds' feet, and the problem arose, 'Can we obtain prints of birds' feet?'

'Print trays' were designed—and constructed—to record the prints of birds that might walk across the soft material inside to reach food on the central island. This was exciting and at once became a class activity. The setting materials tried were Plasticine, and then clay, but these were not very satisfactory.

While these two print materials were being used, the B.B.C. children's television programme, *Blue Peter*, happened to deal with the question of plaster casts of birds' feet. The children asked, 'Could we try plaster of Paris on a print tray?' A tray was filled with plaster of Paris and Bruce was given the task of running to place it on a bird table and then disappearing as quickly as possible. The class was watching at the classroom windows and there was tremendous excitement when the first robin landed on the edge of the table, hopped over the plaster, and reached the food. The hopes of the class on this occasion were amply rewarded by good prints of the robin's feet. In spite of the rapid hardening of plaster of Paris, it provided the best prints. The bird table and print tray are illustrated in figure 58.

Plaster of Paris had other exciting possibilities, and was used to make casts of various sorts. Impressions of bicycle chains, spanners, coins, and an assortment of items were made

FIG. 57. Lucille suggested this way of recording bird watching.



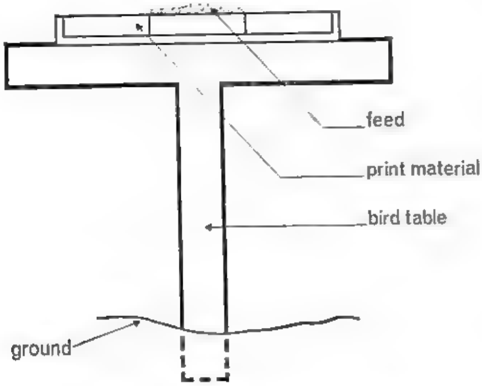


FIG. 58. Bird table with print tray.

in Plasticine and plaster was poured over the mould. They had difficulty in removing the plaques from moulds until two boys returned to school one lunchtime with a number of tin trays that had been found on the village rubbish tip. The teacher insisted that the trays might be used only if they were washed in disinfectant.

Further difficulties in removing the plaques made it necessary to grease the trays. The caretaker supplied Vaseline and this was more successful. When this hint was given on the *Blue Peter* programme a few nights later, the class viewed it with indignation.

Most of the plaster of Paris had been used but before it was all gone Paul thought that a bird plaque should be made. Jean suggested that a mould could be made by pressing a prepared cardboard bird shape into Plasticine. This worked and the same group produced a plaque of a robin and a second one with a blue tit as a centrepiece, shown in figure 59. When painted, the plaques might be judged garish, but not by the children.

Three-quarters of the class had been watching when Johnny Morris appealed on television for help in a bird feeding project. This was organized by the Wildlife Youth Service and Young Ornithologists' Club, and the necessary questionnaires were sent for. On receipt of these it was decided that they should be used by individuals working at home.

Heather brought to school an advertisement for bird food which stated that birds lost one quarter of their weight overnight and it was immediately questioned. Was this possible? Ian thought that birds could be trapped and weighed before and after 'their breakfasts at the bird tables'. This thought was well received by the class. When they spoke about their plans, however, the school welfare officer, an ornithologist, told them how birds were trapped, ringed, and weighed, and said that a licence to trap and ring was required. The class expressed disappointment but readily agreed that there was wisdom in protecting birds and indeed that it was necessary. Although different enquiries began in the new term, the children still maintained one bird table which they stocked and observed regularly.

A woollen mill

The children were speculating about a proposed visit to a local woollen mill and the following questions arose:

'Where do they get the wool from?'
'What kind of sheep provide the wool?'
'How is it [the wool] cleaned?'
'How are the different coloured squares made in rugs and blankets?'
'How long does it take to make a rug?'
'What do the machines do?'
'Why don't they make a great big long blanket and cut it up?'

Anne, who asked the last question, was surprised to find that this *is* done. Although the children did not understand how the spinning and weaving machines worked, they did appreciate the processes involved and on their return to school reconstructed what went on in the mill.

Groups of children prepared a display showing the eight principal processes of making woollens. One group found that they were short of information and asked if they could go back to the mill in their own

time. The teacher agreed to arrange a second visit for them on the following Saturday, but the children went on their own that evening. This was possible because the mill is small and informal and the children knew the work people.

The group concerned with weaving was excited to find in the school stores cupboard some old wooden looms. These were soon in use with an enthusiastic group of girls making woollen cloth. Before the interest in the looms had waned everyone in the class knew how to weave.

Bruce and Brian, who before the visit had asked questions about the mill's source of wool and the types used, were extremely interested in sheep. The teacher thought that an outing might be made to a hill farm, but it was the lambing season and the farmers were overworked so it was inadvisable. Bruce and Brian drew up a questionnaire and those children who lived on farms agreed to collect the information.

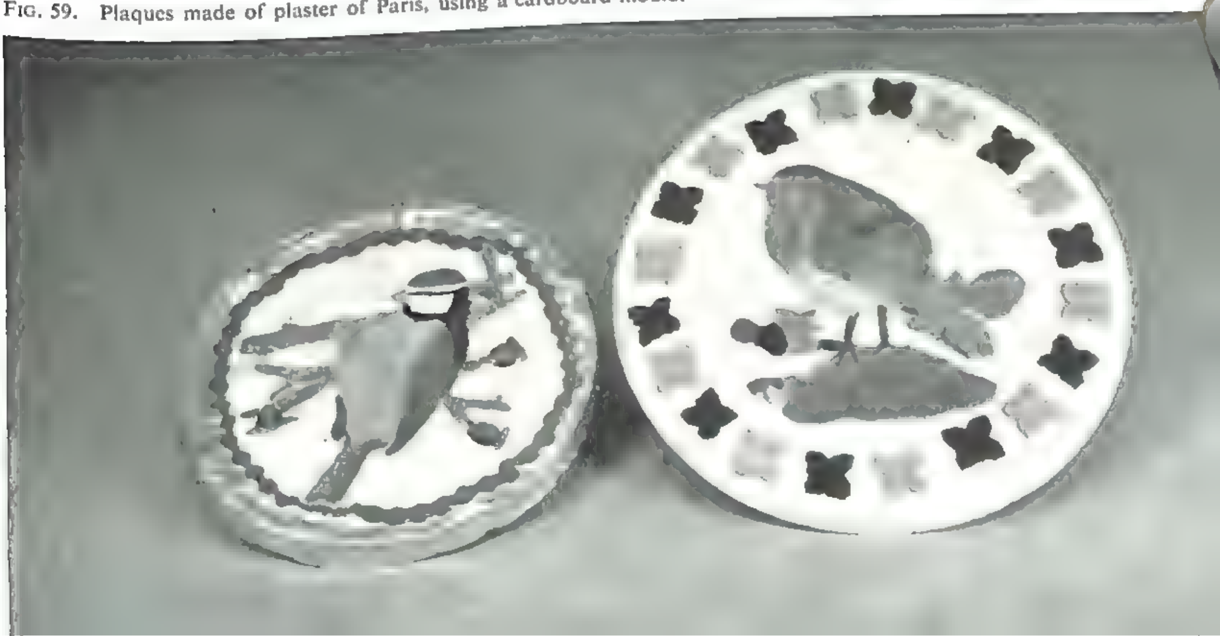
Once members of the class began reporting back, the group summarized the facts on a large chart. This was soon extended when information began to flow in from the farms of relatives and friends, and at this point it seemed right to the teacher that the work might include representative returns from the whole of Britain. With this in mind two members of the group, Jean and Graham, compiled a new questionnaire.

A group examined samples of the wool they had brought back. Lucille had begun by merely snapping the different samples, but with weights readily available in the classroom they soon began to measure the breaking points of the pieces of wool. The children designed a stand to hold the wool and this, quickly constructed, worked simply and efficiently. The breaking point of each sample of wool was found by adding slotted weights to the holder until the wool broke. The apparatus is outlined in figure 60.

The act of deliberately breaking things seemed to be attractive and various types of paper were tested for strength after this, and the results recorded in a graph. The group who had designed the 'breaking point apparatus' next adapted it to find the breaking point by crushing. Figure 61 shows how the first object tested was a jam jar and this withstood all attempts—including boys standing on the roof—to break it. At this juncture the teacher thought it safer to restrict the tests to 'pulling' rather than allow 'crushing'.

Jean and Graham had made an attractive chart summarizing the details of the local lambing season, just ended. Brian, who had produced a large map of the British Isles on which to display the answers he anticipated

FIG. 59. Plaques made of plaster of Paris, using a cardboard mould.



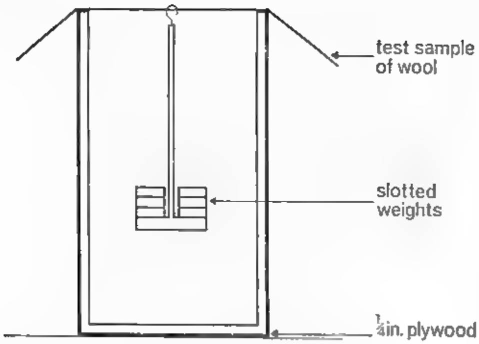


FIG. 60. The wool breaking apparatus.

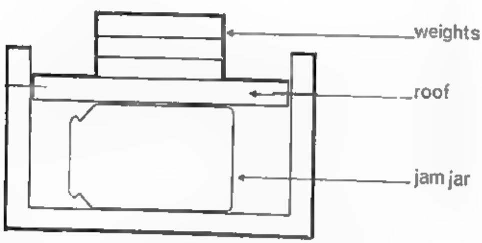


FIG. 61. The crushing chamber in use.

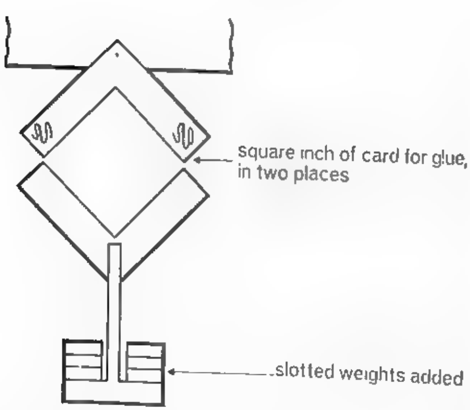


FIG. 62. Apparatus designed to compare setting times of glues.

from the two questionnaires, grew impatient when nation-wide addresses could not be obtained, and sent off the first questionnaire himself. It went to a champion racing driver who farms in Berwickshire and who had on occasions sold stock to Brian's father. Distant addresses of farms were not forthcoming but the racing driver replied personally to Brian, returning the completed questionnaire and including a signed photograph of himself in a racing car; this compensated fully for the questionnaires that were never sent. In any case, the local lambing returns provided many points for discussions.

The group that was testing the strengths of papers, including newsprint, brown wrapping paper, sugar paper, art paper, and other kinds, used one-inch strips and, at the teacher's suggestion, repeated the tests numerous times to determine the average breaking point for each paper. The results were displayed as a large block graph and chart which incorporated actual test samples. The same group then found the breaking points of rubber bands of varying thicknesses.

The teacher, fostering the children's interests in the strengths of materials, supplied them with twelve different brands of glue in tubes. A large group of boys immediately took these materials over.

'Which glue is the quickest to set?' asked Paul. The boys discussed the most efficient way of finding out. The experimentation which followed, described in figure 62, was to take two triangular strips of card of equal size and apply glue to the two ends of each. It was carefully applied to areas of one square inch in each case, and then the two strips were joined together where glued, now forming the outline of a square. Now the square was hung from an unglued angle, on a nail, and weights were hung from the opposite corner after the glue had been applied for one minute, two minutes, and so on. A stopwatch was used to time each test. A number of subgroups formed to test each glue and provided Paul with the answer to his question.

One child asked 'Are some glues better when they're used on different things after they set?'

The first thing they had to do was devise a method of measuring the force needed to break adhesion. They tested balsa wood first, by the method shown in figure 63. But heavy weights were required and none was available. One group had been thwarted earlier in the term when there had been insufficient weights to break the jam jar (by crushing), and it seemed that this might happen again, until Patrick suggested using bricks. This was the answer until the string proved too weak to hold 40-50 lb. of bricks. Ian made a wire cradle to hold the weights.

When the children found it difficult to support the test materials and weights between desks, the school caretaker provided an old blackboard easel. This worked admirably but with the increased height of fall the bricks were now in danger of breaking. To prevent this Ian stacked P.E. mats under the easel, as shown in figure 64.

The children who used glues on rubber and glass found it difficult to measure the breaking points accurately. They therefore pulled the joints apart by hand and estimated the pull required in a five point scale. The results of the assessment were recorded in the form of a 'league table'. Even the carefully measured results were converted to the points system and included in the league table recording.

When testing glues on other materials, one group discovered that when two strips of hardboard had been glued together the hardboard broke before most of the glued joints.

At the end of the term the children staged an exhibition.

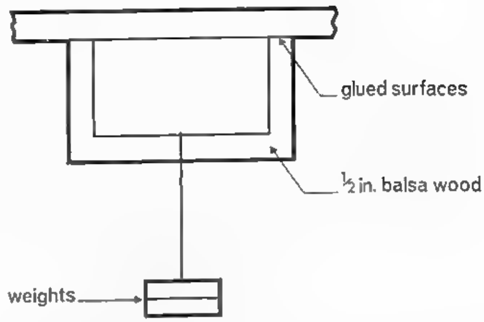


FIG. 63. Apparatus designed to test glues on balsa wood.

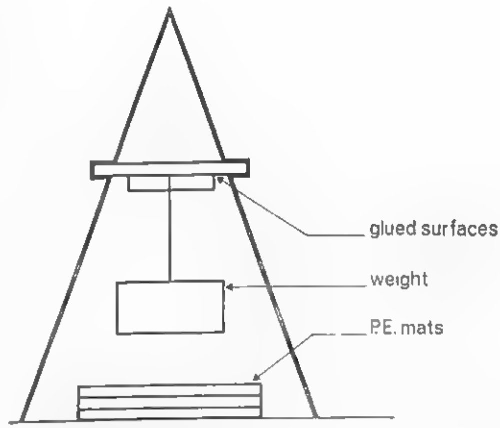
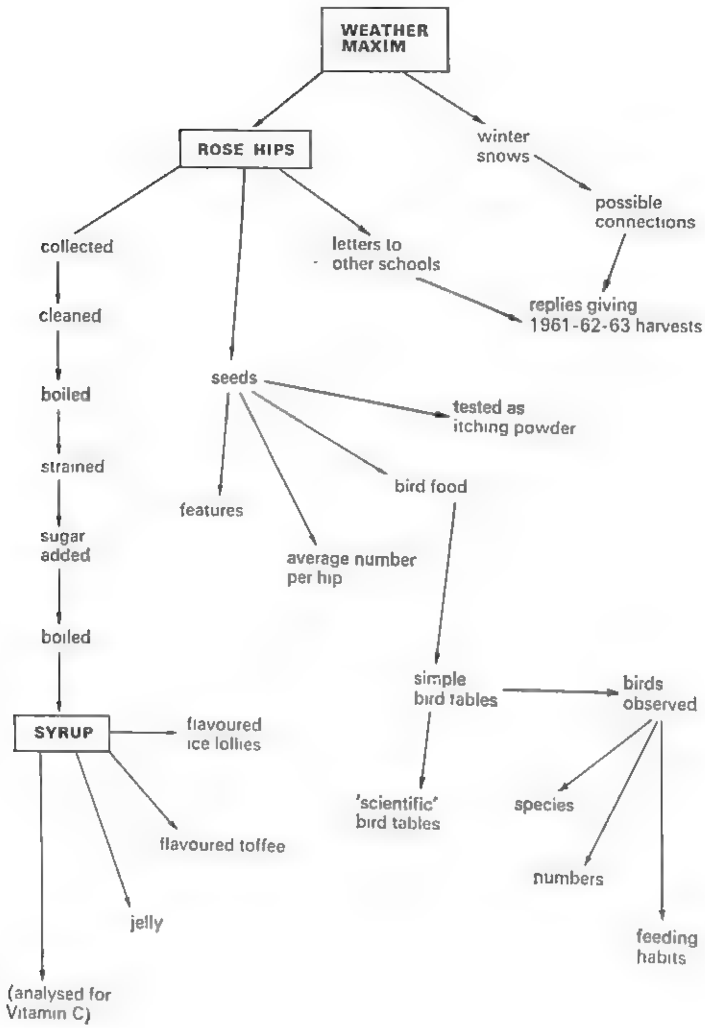
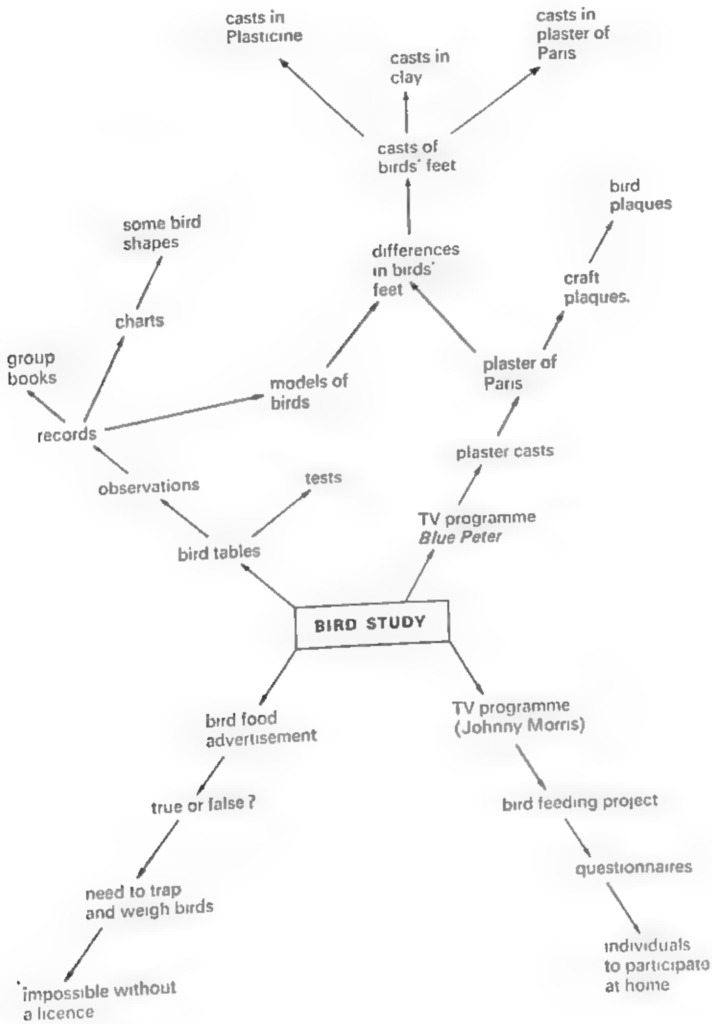
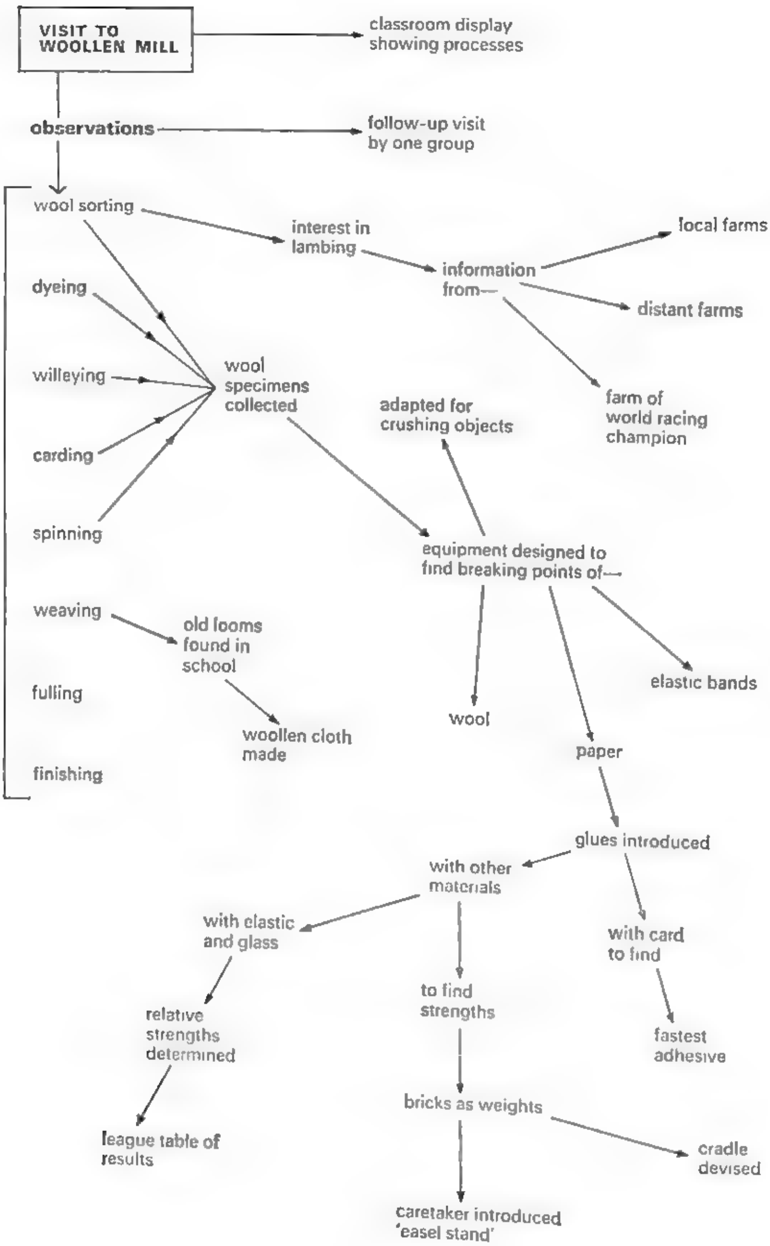


FIG. 64. The children also used the blackboard easel to test the strength of glues.


WEATHER MAXIM
ROSE HIPS
winter snows
possible connections
collected
letters to other schools
replies giving 1961-62-63 harvests
cleaned
boiled
seeds
tested as itching powder
strained
bird food
features
sugar added
average number per hip
boiled
simple bird tables
birds observed
SYRUP
flavoured ice lollies
'scientific' bird tables
species
flavoured toffee
numbers
jelly
feeding habits
(analysed for Vitamin C)


casts in Plasticine
casts in clay
casts in plaster of Paris
casts of birds' feet
bird plaques
some bird shapes
differences in birds' feet
craft plaques.
charts
group books
models of birds
plaster of Paris
records
plaster casts
observations
tests
TV programme Blue Peter
bird tables
BIRD STUDY
bird food advertisement
TV programme (Johnny Morris)
true or false?
bird feeding project
questionnaires
need to trap and weigh birds
individuals to participate at home
impossible without a licence


VISIT TO WOOLLEN MILL
classroom display showing processes
observations
follow-up visit by one group
wool sorting
dyeing
willeying
carding
spinning
weaving
fulling
finishing
interest in lambing
information from—
local farms
distant farms
farm of world racing champion
wool specimens collected
adapted for crushing objects
equipment designed to find breaking points of—
old looms found in school
woollen cloth made
wool
paper
elastic bands
glues introduced
with other materials
with elastic and glass
relative strengths determined
league table of results
to find strengths
bricks as weights
caretaker introduced 'easel stand'
cradle devised
with card to find
fastest adhesive

29 Urban wasteland

Class	**9-11 years. Full range of ability**
Class number School roll	29 boys and girls 80
Term	Autumn
Building	1900. Soon to be demolished
Classroom	Modern furniture
School environment	Urban. Close to heavy industry and gas works. Serving slum clearance area.
Local setting	North-east England. Port and industrial area: iron and steel making and associated industries; chemicals.

Keith could hardly wait to tell everyone, 'There's a beehive on the common!' They all wanted to see it, so the teacher suggested that they should go and look. Perhaps they might find other interesting things and creatures. The 'common' is a piece of wasteland on which slum houses once stood and which has now been colonized by a variety of plants.

They found the bees living in a hole in the wall alongside the railway embankment and after watching them for a while the children searched for other creatures. They were astonished at the number they found. There were spiders, harvestmen, grasshoppers, woodlice, slugs, devil's coach horses, craneflies, leaf beetles, a small white butterfly, a hairy black caterpillar, and many others. In their excitement the children asked few questions other than:

'What is it?'
'Will it hurt me?'
'What does it eat?'

Some of the creatures which were taken into the classroom were housed in tanks containing soil, stones, and plants; others were put into plastic lunch boxes or cages made from acetate and cheese boxes. Soon the children were absorbed in watching them. A few tried to find out what they were from reference books; others made simple crude drawings. There was much discussion.

Within a fortnight the children were observing closely and asking many questions. A few began to follow up their questions with experiments, but mostly they continued watching and handling their specimens. They worked alone or in small groups, followed their own inclinations, and showed little interest in other people. The teacher provided the necessary materials and moved from child to child discussing work and listening to all they had to say.

Brian tried to find out what conditions his devil's coach horse preferred. He covered half

of a plastic lunch box with black paper, put the beetle in the centre, and watched which way it went. Dennis sloped his container until his beetle remained in the same spot with all its legs moving, then went on to see which surfaces it could grip easily.

Those who were keeping slugs noticed that their trails made a map of their movements. They dusted chalk on the wet trails to make them easier to see, deciding that white chalk on black paper was best. At first, Stephen used string to measure the lengths of their trails, but later he made a trundle wheel from a cog of an old alarm clock. One night a large slug escaped and crawled twenty-one feet from its cage. Bobby noticed that the trail ended suddenly and the slug was part of the way back along it. He thought that it might be using the trail to find its way home again and tried to test this idea.

They devised experiments about food preferences. They discovered some accidentally, as when a devil's coach horse ate an earwig, and established others by offering a choice. Also, they calculated the quantity of green leaves eaten by a slug in one day, and in order to see exactly how it ate, mixed some flour and water, smeared the mixture on a piece of acetate, and watched from below as a slug fed. Robert announced, 'I know how slugs eat. They kind of scrape,' and was delighted by the scraping sounds made by a large black slug as it ate a leaf.

There were moments of intense excitement when the unexpected happened. Linda and Barbara saw ichneumon fly larvae emerge from a caterpillar and change into cocoons, and asked for books to find out more. Dennis was astonished when his devil's coach horse flew across the room. This started him examining other beetles to see if they had wings. Christine watched her slugs lay eggs and wrote her own booklet about it. Experiences like these resulted in discussion, writing, and drawing, as the children wanted to communicate their findings.

More slugs' eggs were found and Lynne tried to find the best conditions for hatching. Spiders aroused great interest. Dennis tried to persuade one to eat dead flies. He watched it spin a web and made a coloured drawing of the various stages of construction.

He teased out an egg cocoon, counted the number of eggs, and with Barbara made an inch of eggs in order to find the size of one.

The children's work spilled over into their spare time. Carol and Pauline had seen a bee on the common getting nectar by 'sticking its tongue right down into the petals'. Keith said, 'There's a beehive in the museum and you can see the bees going in and out.' Three of the boys made a hive, working from Keith's description. They set it up on the common, but it was destroyed. In any case, Alan had insisted that if they wanted bees to use it they would have to catch a queen and put her in first.

The children noticed that they didn't always find the same number of creatures on every visit to the wasteland so, at the teacher's suggestion, they agreed to select a number of small plots and study the animal population in each one. They knew that marker pegs would be destroyed, so they measured and mapped the common and showed the position of each plot on the map. They made their own instruments and had to devise methods of fixing a position on the map.

Towards half-term the teacher wrote,

> 'The children are much more aware of their environment than they used to be, and are constantly discovering objects of interest. Mere identification of a creature will not suffice. They wish to know more about the creature and are prepared to go to some trouble to find out. For example, a cockroach was brought in by Norman and Robert. They were arguing about its sex. They remembered that we had a set of pictures showing male and female cockroaches, but nobody knew where they had been stored. They made a thorough search, and with help, unearthed the pictures to confirm Norman's opinion that it was a male. They observe more closely now and ask more detailed questions.'

During the second half of the term the

children began to gather pieces of waste material from demolition sites. They were spread out on a table in the classroom. The teacher gathered together those who were interested in materials and they discussed these. When he asked them what they wanted to find out, they were full of ideas. For example:

'Does it bounce?'
'Can it bend?'
'Can it stretch?'
'Will it break?'
'Can you cut it?'
'How heavy is it?'
'How big is it?'
'Can you scratch it?'
'Does it go rusty?'
'What does it feel like?'
'What does it look like under a lens?'

Each child chose a piece of material to examine. Some bent their materials backwards and forwards, others dropped a weight onto pieces of wood resting on two bricks, and one or two used a spring balance to find the breaking strain of fibres and pieces of rubber. They all wrote about their discoveries.

Following this free investigation they held a reporting session which soon developed into a question time as children asked about the problems arising from their experimentation.

ROBERT: Why doesn't rubber float?
BARBARA: Why does sponge rubber change colour when it gets wet?
BRIAN: What is that—like string—made of? (*It was part of an electric cable.*) May I look at it through the microscope?

As each child asked his question, others suggested ways of finding an answer. This marked a change in the children's attitude. Previously they had been absorbed in their own investigations, now they were interested in other people's problems as well and were ready to cooperate.

Their knowledge of materials was put to use as Christmas drew near. Every year, they stretch strings across the school hall and hang decorations. Stephen brought some string but it seemed too thin and weak. They decided to test its strength with a spring balance and found that it needed a 20 lb. pull to break it. They discussed what to do next and many suggestions were offered:

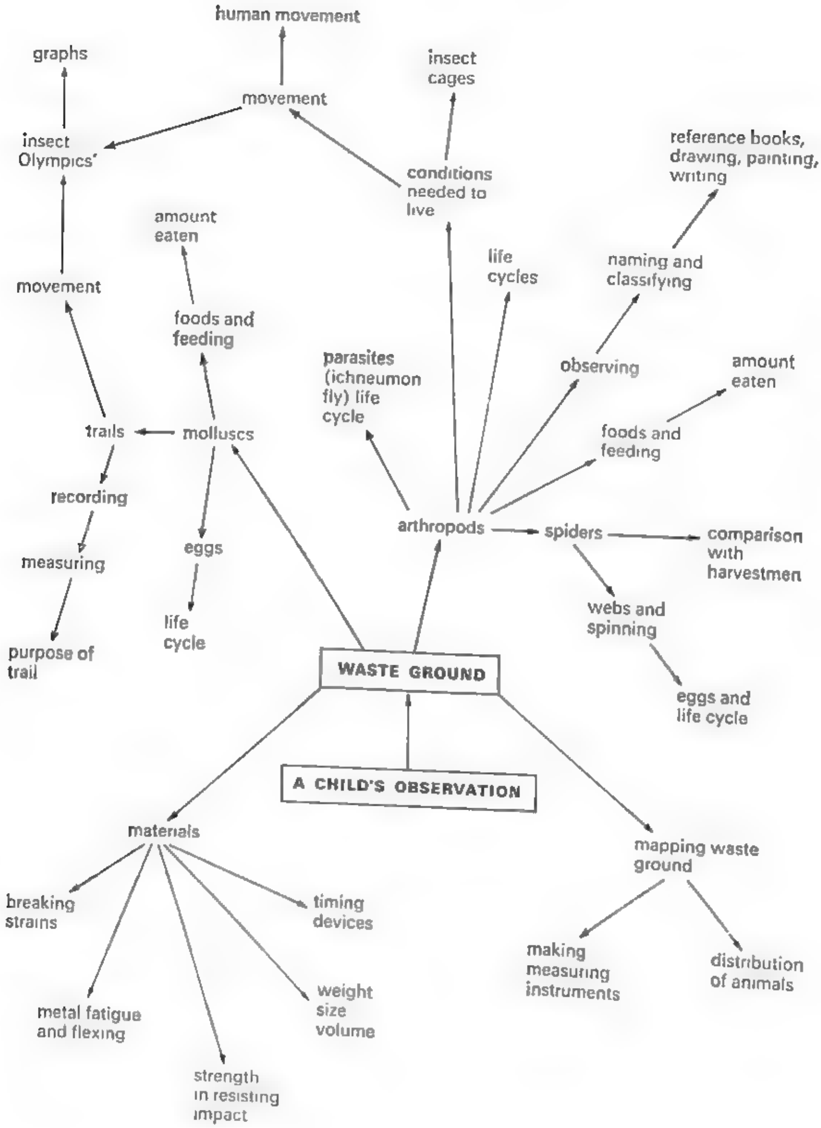
GRAHAM: Hold a piece of string at each end, load it with decorations, and see if it breaks.
ALAN: Put the decorations up and see.
LAWRENCE: Weigh a quantity of the decorations enough to load one string.

The teacher wrote:

> 'The class decided that Lawrence's suggestion was the most promising, so we followed it. The weight of the decorations was only 8 oz. so we went ahead with confidence. As the children moved off to begin hanging up the decorations, Graham remarked that the load would be spread right along each string, therefore we had extra safety.'

The 'insect Olympics' led to an interest in timing, and scrap materials were used to make timers. Sand glasses were made from empty plastic bottles and an unusual timer was made from a metal tube, a wooden block, and a ball bearing. A boy closed one end of the tube, then rested the other on a block of wood. The ball bearing was placed in the open end of the tube and he could hear it hit the bottom. He altered the position of the block until it took the ball bearing exactly five seconds to travel down the tube. These timers were in constant use.

By the end of the term most of the children had turned their attention to the study of materials and they were determined to carry on with this after the holiday.


human movement
graphs
insect cages
movement
insect Olympics'
reference books, drawing, painting, writing
conditions needed to live
amount eaten
life cycles
naming and classifying
movement
foods and feeding
parasites (ichneumon fly) life cycle
observing
amount eaten
trails
molluscs
foods and feeding
recording
arthropods
spiders
comparison with harvestmen
measuring
eggs
webs and spinning
life cycle
purpose of trail
WASTE GROUND
eggs and life cycle
A CHILD'S OBSERVATION
materials
mapping waste ground
breaking strains
timing devices
making measuring instruments
distribution of animals
weight size volume
metal fatigue and flexing
strength in resisting impact

30 A woodland visit

Class	**9-11 years. Special class, remedial with slow learners**
Class number School roll	23 boys and girls 1,100
Term	Autumn
Building	Class in wooden annex
Classroom	Space adequate. Storage minimal, water not available in annex, but gas tap in the classroom.
School environment	School set in large grounds laid out in sports pitches. Variety of hedges on school boundary. School situated in a residential area in a large city.
Local setting	Northern Ireland. A large industrial city. Immediate surroundings completely built up. Light engineering works near.

The class visited a woodland area near the school where the pupils were given an opportunity to search, observe, and collect what interested them. Back at school the specimens were sorted and labelled, and from the discussions and questions there arose four centres of interest: trees, stones, spiders, and floating and sinking. Later in the term, six groups of pupils were working, including two additional groups studying sand and flowers. Pupils grouped themselves as they wished and were free to change.

Trees

The pupils working on trees asked many questions, among them the following:

'Why are trees slanted?'
'Why do chestnuts grow on trees?'
'What is wood made of?'

In the early stages, the children spent much time on questioning and discussions, but eventually they took cuttings of trees and planted them. Some were put into jam jars of water, while others were planted in a small garden outside the classroom. Daily observations were made.

The children spoke of taking 'snips', and additional plants were brought in: *Tradescantia*, *Chlorophytum*, geraniums, *Kalanchoe*, and saxifrage. The children took cuttings from all of these, planting some in soil and standing some in water. One girl brought back a reedmace, after a week-end car trip, and planted the seeds in very muddy soil. Other pupils collected haws and chestnuts and

planted them in the garden, in boxes, or in pots.

The potted plants the children brought into the classroom started discussions about soils and what they are made of. The soil in the pots was seen to be different from the soil in the school garden, and one boy said that the soil in one of the pots included peat and sand. He sorted out a sample of each to prove his point.

The group talked of the effects of soils on the way plants grow. They made seven different mixes of soil using sand, peat, and loam, and pots were filled with these 'soils', and peas planted to see what would happen.

One boy steeped half a jam jar of peas and found that later they more than filled the jar. He then weighed the peas and found that they had increased in weight. For weights he used sticks of chalk; he noted that the soaked peas were twenty sticks heavier.

Another boy weighed five peas, using leaves as weights. He collected leaves of the same size and species. His five peas weighed ten leaves, so he concluded that one pea weighed two leaves. He is seen at work in figure 65.

Bulbs were asked for by the class and these, too, were planted in different soils. Two of the tulip bulbs were cut open, one horizontally and one vertically, and drawings were made. The children counted the layers of skins and planted pieces of bulb to see if they would grow. At the end of term they potted their original cuttings and started to talk about fertilizers.

Just before the bulbs were studied, two boys began a study of flowers, while the other children measured the growth of an onion's roots. A complete wallflower plant was minutely studied, detailed drawings were made, and a display was put on for the rest of the class.

Spider

One boy asked a question which intrigued his group: 'How does a spider make a web?' The members spent a long time looking for spiders in the school grounds. They were particularly anxious to see this animal at work. The food of spiders was discussed and some were watched as they ate flies. Some children commented on the patterns on the bodies of the spiders. Others compared the movements of a spider and a harvestman, finding that the spider they released walked between the grass stems, while the harvestman went over the grass.

The children examined the wing cases, wings, and legs of ladybirds by watching them take off into the air, and this started a close study of spiders' legs, feet, mouths, and palps.

FIG. 65. Weighing peas.

Some pupils made webs using thread sewn onto cloth, while others experimented with wire and cord.

At this point, someone found an earwig with an oval object coming from the tip of its abdomen. This was said to be an egg, and there followed a long discussion on the role of male earwigs and the function of the pincers.

Some children made cages for the animals from polythene and lunch boxes, while at home, Paul wrote a book on 'The Life of Insects'.

Floating

A group of girls asked, 'Why does wood float?' They made a collection of objects including blackberries, paper, stones, and wood, and tested which floated and which did not. At home Pearl consulted an encyclopaedia and reported: 'It floats because it is lighter than water.'

The children now set out to see if this was true, and at the suggestion of the teacher, borrowed scales from an adjoining classroom. They took a considerable time finding out the workings of the scales and then placed a stone on one pan and a piece of wood on the other.

The stone was heavier than the wood, but Pearl commented on the need for both objects to be similar in size and the following day brought a tile and a square of plywood of the same size. They all agreed that these could be compared and weighed.

To compare the weight of wood and tile with that of water created a problem until the teacher suggested that Plasticine might be of some use. The Plasticine was moulded round the tile and then the mould was filled with water. The mould with water was now weighed against the tile but this was seen to be 'unfair'. In subsequent weighings an equal amount of Plasticine was placed on the other balance pan. The children now demonstrated that wood was lighter than water and stone was heavier than water, by putting a Plasticine mould with stone or wood on one pan and a Plasticine mould filled with water on the other pan.

It was seen that very small but 'heavy' things would float on water; wire sewing needles and pins were tried. The children observed the dimpling of the surface of the water and talked about the 'skin' of the water.

One girl stated that it was possible to make a hole in the aluminium top of a milk bottle without the milk coming out when the bottle was turned upside down. This was tried and found to be correct. The hole was now made larger, a suggestion made by the teacher. When the hole was 12 mm. square the milk gushed out.

Lynn placed a number of objects which floated, including an electric light bulb, in a plastic basin. The bulb floated, she said, because it had air in it and this was also the reason that a small medicine bottle floated. If the air were removed it would sink, she thought. Pearl suggested that boiling water in the bottle would remove all the air. This was an idea she had heard about from her older brother at secondary school. The problem here was that she could not think of a way to boil water in the glass bottle, so a pressure can was provided by the teacher. Water was boiled in this, the cork replaced, and the can put into a basin of water to see if it would float. The tin collapsed, but Lynn commented that it was still floating and so must have some air remaining in it. Finally, the tin was squashed flat in a vice to rid it of air, and then it sank.

The collapse of the tin came as a surprise and when the cork could not be pulled out comments were made about what was holding it in. One can was pierced with a nail and a hissing note was heard. Someone suggested that the air was coming out, but this was queried by the teacher. A discussion with the teacher followed, about finding out if the air was escaping from the tin or going into it, and it was decided to pierce another tin when it was being held under water. The water gushed into the tin when this was done and no one doubted that the noise had been made by the air rushing in.

An aluminium lozenge tube was flattened in a vice to remove all the air, and placed on water. This flattened tube floated, so the children put nails on it until it sank, noting how many nails were needed. When one girl put her hand into the water to pick up the tube and nails, she noticed that the water level rose. This was discussed, and later they talked of ice floating on lemonade. One of the girls brought ice cubes into school and these were floated in water. The patterns of bubbles in the ice cubes attracted the pupils' attention and they made drawings.

From this group of girls, two formed a sub-group. 'What is sand?' they asked. The origin of this question is unknown, but it may have been stimulated by the work being done on the making of soils. The girls looked at the sand through a hand lens and graded it by size of particles. They then examined soil to find its constituents. They discovered pieces of cement, ground these into a powder and mixed it with sand and water to reconstitute cement, and then tested its properties.

Stones

A group of boys asked the question, 'What are stones?' They had made a collection of stones, and in answer to their question the teacher suggested they might break some of them open and look at them carefully. Next day, one of the boys said that he knew what stones were made of: 'They're made of minerals.' This answer, probably derived from a book or a parent, seemed to satisfy the boys, who now concentrated on making sparks. They did this by striking together a great number of different kinds of stones.

Amongst their collection were some pieces of brick and cement, and these started them making their own stones. They brought cement and sand and made cement blocks of various mixes, altering the ratio of both ingredients. Their belief was that the greater the amount of sand, the weaker the block would be.

The blocks were tested by dropping a stone onto them from a height of 25¾ in., as the boys in figure 66 are doing. The first stone was soon seen to be too heavy, as it broke all the blocks in one or two drops, so the remains of the blocks were tested with a lighter stone.

The blocks had been cast in moulds made of chalk boxes, and varied a great deal in thickness, so a new set of moulds was made from wood and hardboard. The size of the blocks was 6 in. × 3 in. × 2 in. Now the children used one measure of cement and varied the measures of sand, and allowed the blocks to dry well before testing. An additional brick was made of thistle plaster.

The test stone used was the lighter of the two and weighed between 2 lb. 3 oz. and 2 lb. 4 oz. Greater accuracy than this could not be obtained as only 1 oz. weights were available.

The teacher discussed the possibility of finding more accurately the weight of the stone, and suggested they make their own weights. A variety of materials was thought of, but eventually a 1 oz. weight was made from Plasticine, cut into two parts to make two ½ oz. weights. These were checked against each other to ensure they were of equal weight.

FIG. 66. The boys tested the strength of the blocks they had made.

The light stone was now weighed at 2 lb. $3\frac{1}{2}$ oz.

The testing of the blocks gave the following results:

Cement/ sand mixes	1/6	1/5	1/4	1/3	1/2	1/1	Plaster
Drops	2	4	6	6	23	43	43 (unbroken)

These results were shown as block graphs. The result of the 1/3 mix was queried by the pupils, who said it was a 'bad block'. 'It should not have broken at six drops.' When asked at how many drops it should have broken, they made estimates ranging from eleven to sixteen. They eventually decided on fourteen as the most likely. The 1/3 mix block was made again, allowed to dry, and then tested. It broke at the fifteenth drop.

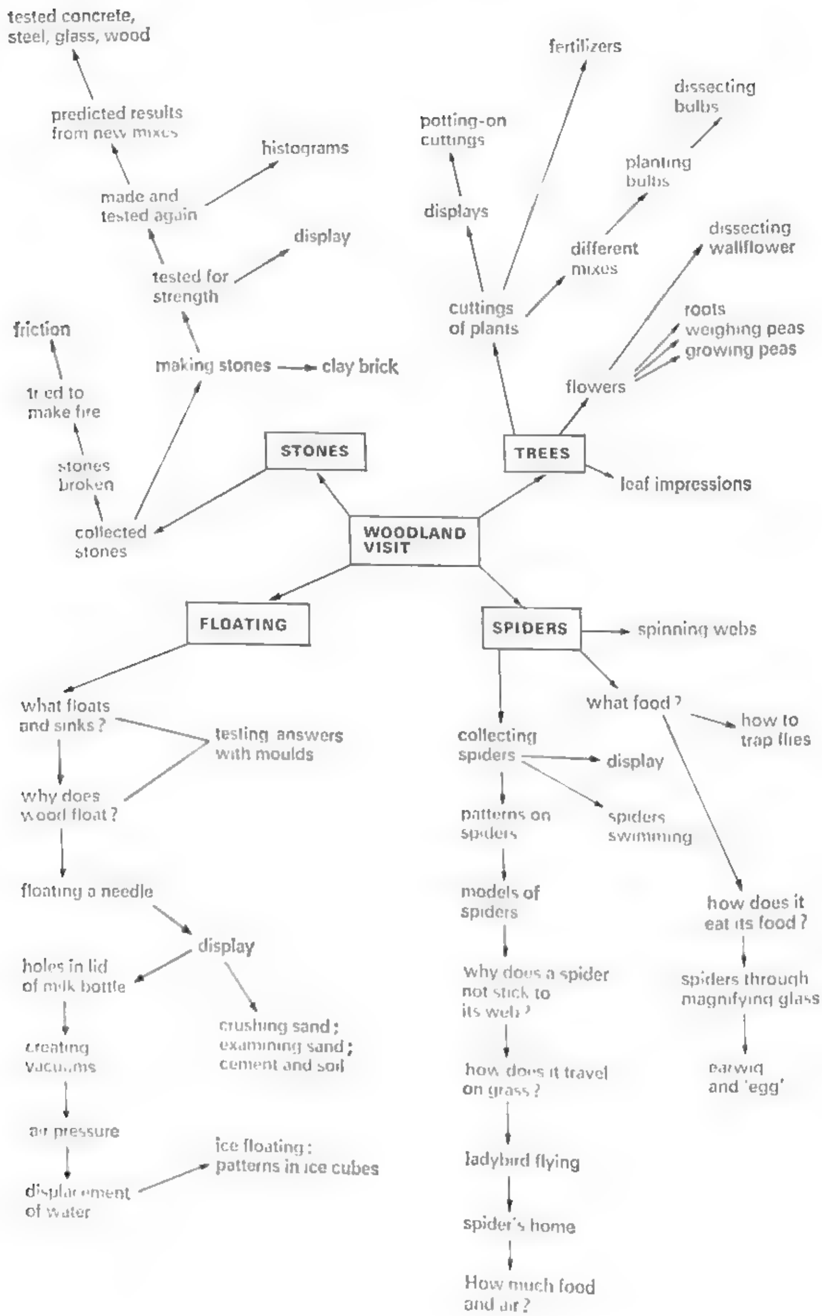
One boy talked about the breaking point of 'half-mixes'—that is, units of $1/2\frac{1}{2}$, $1/3\frac{1}{2}$, $1/4\frac{1}{2}$, and $1/5\frac{1}{2}$. He made some such mixes and tested them, estimating the number of drops beforehand.

Cement/Sand	$1/2\frac{1}{2}$	$1/3\frac{1}{2}$	$1/4\frac{1}{2}$	$1/5\frac{1}{2}$
Estimate	16	10	6	3
Test results	8	11	6	4

A block graph was made of this, and two pupils made others to show the weights and heights of pupils in the class.

Discussions now turned to the physical properties of other materials, such as glass, steel, wood, and concrete with a core.

Glass, wood, and steel were tested by dropping stones on to them, but a reinforced block made to the specifications 18 in. × 1 in. × $\frac{1}{4}$ in. was not a success.


WOODLAND VISIT
STONES
collected stones
stones broken
tried to make fire
friction
making stones
clay brick
tested for strength
display
made and tested again
histograms
predicted results from new mixes
tested concrete, steel, glass, wood
TREES
leaf impressions
cuttings of plants
displays
potting-on cuttings
fertilizers
different mixes
planting bulbs
dissecting bulbs
flowers
dissecting wallflower
roots
weighing peas
growing peas
FLOATING
what floats and sinks?
testing answers with moulds
why does wood float?
floating a needle
display
holes in lid of milk bottle
creating vacuums
air pressure
displacement of water
ice floating: patterns in ice cubes
crushing sand; examining sand; cement and soil
SPIDERS
spinning webs
what food?
how to trap flies
how does it eat its food?
spiders through magnifying glass
earwig and 'egg'
collecting spiders
display
spiders swimming
patterns on spiders
models of spiders
why does a spider not stick to its web?
how does it travel on grass?
ladybird flying
spider's home
How much food and air?

31 Animals in the school grounds

Class	**10 years. Third stream of a four-stream year**
Class number School roll	43 boys and girls 1,100
Term	Autumn
Building	Built in 1930s. Pleasant, but few services near classroom.
Classroom	Room with dual iron-framed desks. Good display boards, little storage space.
School environment	School set in large grounds laid out in sports pitches. Variety of hedges on school boundary. School situated in a residential area in a large city.
Local setting	Northern Ireland. A large industrial city. Immediate surroundings completely built up. Light engineering works near school.

At the beginning of the term, in September, the pupils studied the school grounds as part of a general approach to finding out about their surroundings. The grounds are well cared for, being games pitches, and the great variety of wild animals to be found came as as a surprise to the pupils.

They quickly discovered that the best areas to search for small animals were those close to the hedges as in figure 67, or around piles of stones or soil, near grass cuttings, or around machinery that had been standing for some time. Interest in the animals soon led to requests for permission to bring them indoors for further study.

Elaborate cages were made from pasteboard boxes and adhesive tape, but as none of these was really successful, a succession of cage models was tried, each showing improvements as the pupils grew to appreciate the needs of the various animals. At the same time there developed refined methods of trapping animals in jam jars and cans. This could have developed into an interesting investigation, but local children coming into the grounds soon discovered the traps and interfered with them, so the activity stopped.

It was at this point that the teacher brought plastic lunch boxes into the classroom, in the interest of the animals. The class soon converted these into excellent vivariums. In addition, Polyglaze sheeting was used to produce excellent cylindrical cages for spiders.

The attitude of the pupils to the animals was interesting. At first they were quite unaware of their needs and showed a lack of interest in their well-being, but later they were much more concerned for them, almost to the extent of thinking about them anthropomorphically. In making homes for them,

their aim was to make the animals happy, but by mid-term onwards they showed a much fuller appreciation of the importance of physical factors, such as moisture, temperature, food, etc.

It was as they trapped small animals out of doors that they noticed rooks feeding on the hockey pitches. One pupil wanted to know what they were feeding on, so they searched and saw an apple core and some bread crumbs being eaten. They looked carefully but could see no other food on the area on which the rooks were feeding. However, they noticed holes in the soil and associated these with the way the birds probed the soil with their beaks, presumably looking for small animals. (Nevertheless some children thought at first that the holes might have been made by wheels of grass-cutting machinery. Others suggested stiletto heels, while some thought they were made by the studs of football boots. All of these possibilities were investigated, the last two by pressing a stiletto heel and a stud into soil but the holes produced were not the same size and depth as those already on the pitch. The wheels of the grass-cutting machine were seen to be too large.)

Sample sods were dug and examined in the classroom. As most produced earthworms only, the class decided that this was the food being looked for by the rook.

Each sod was 6 in. square and 3 in. deep. The pupils chose this depth deliberately when they had estimated that a rook's beak was not much more than 2 in. long.

At this time, they posed two main problems:

1 How many earthworms are there in the school grounds?

2 How many rooks feed in the school grounds?

After a good deal of cogitation, the class agreed to attempt to *calculate* the number of earthworms in a hockey pitch. This was in the nature of a compromise, for at first the only course had seemed to be to dig up a complete pitch to collect the worms.

However, through discussion between the group and the teacher it was decided to dig a number of sods 12 in. square and 2 in. deep. These were brought back into the classroom and broken up, and the total number of

FIG. 67. Searching for small animals.

worms in each was counted. There was variation, between two and twenty-nine, in the numbers of worms found in a sod.

There were comments about these numbers and about the likely numbers in any one sod. At this point, the teacher talked to the children about the idea they were struggling towards, namely, averages, demonstrating the use of these in sport or in expressing the weights and heights of school children, and explaining how to compute them.

They were now able to calculate the average number of worms occurring in the sods. This was seen to be useful in the calculation of the total earthworm population of the hockey pitch, as all they needed to know now was the number of sods 12 in. square in the pitch.

Two children attempted to measure the pitch by pacing it out and two others set off with a foot rule. The two results did not tally, so the limitations of the techniques were discussed and the pitch re-measured, first with a metre stick, suggested by one boy, and then a surveyor's chain provided by the teacher.

The number of squares and the total earthworm population were calculated. The population was found to be 800,000, a figure which amused everyone, for even to count to 800,000 takes such a long time. One boy did work out the time needed by timing how long it took to count to 100 and multiplying by 8,000 and allowing time, of course, for sleep and meals.

The size of the sod 12 in. square was chosen quite arbitrarily by the children and in discussion, the teacher spoke of this as one square foot. The number of square feet in the hockey pitch was known now and one child talked about square yards and square inches. This started three girls working out the relationship between square inches, square feet, and square yards. They produced a series of squares of different sizes, and tables showing the relationship between each. The samples had been taken along the touchline of the pitch and there were many comments to the effect that there might be fewer worms nearer the middle.

For instance, it was suggested that:

1 The sods taken were from places where fewer people walked and the soil would not be trampled down.

2 Lime used for marking out the pitch would kill the worms.

3 Tractors, machinery, and boot studs would kill them.

4 Rooks fed on them, and it rather looked as if there must be more near the hedge since cats were frequently seen lurking there.

This work evoked all sorts of queries and problems:

What happens to worms when the ground is trampled?
Are there more worms in banks?
Does the water run off the banks and affect the worms at the join with the pitch?
Are there many under the school?

One boy suggested that worms liked moisture and heat and lived in the earth in a place where they had sufficient moisture from the surface and heat from the Equator. (By Equator, this boy meant the centre of the earth, which he had read was hot enough to melt rocks.)

More sod samples were dug, therefore, and in one sod one worm only was found. This result was unlike all the others and aroused great interest, especially when someone noticed that the soil was different. It was red and sandy, compared with the brown soils of the other samples.

Again came a variety of queries and statements:

'Do worms not like this soil? Why not?'
'It dries up more quickly.'
'It doesn't contain food.'
'It may contain the worms' enemies.'
'Are there two types of worms? One which likes red soil?'
'Does the worm actually live in red soil or was it passing through?' (The boy who suggested this had found that the red soil occurred only in narrow veins.)

Paul was especially interested in these

problems, and Stephen and he devised a series of experiments to find out if worms prefer red or brown soil. They can be seen at work in figure 68. Stephen suggested putting both types of soil into a basin, one side being filled with red and the other with brown soil, and then introducing a number of worms. It is interesting that after two or three days they suggested that they could find an answer by taking samples from both soils. These two boys eventually had five sets of apparatus.

1 Basin containing half red and half brown soil; ten worms put into brown soil, none in red.
2 As above, but ten worms put into red soil and none in brown.
3 As above, but five in each.
4 Red soil at one side of basin, brown at other, but a gap of several inches between them with ten worms placed in the gap.
5 Soil arranged so as to produce a band of red soil across the centre of the basin and ten worms placed in one section; this was to find out if Paul's original idea of the worm passing through was correct.

This was a most sophisticated piece of work and well documented, although not productive of clear-cut results.

FIG. 68. One of the tests to determine whether worms prefer brown or red soil.

The statement, 'It dries up more quickly', led two boys to carry out a series of weighings of samples of brown and red soil. They had no scales but were not deterred, and made a balance of balsa wood. This, however, was not sensitive enough and they later used a spring balance, provided by the teacher. They found that their original idea was quite correct.

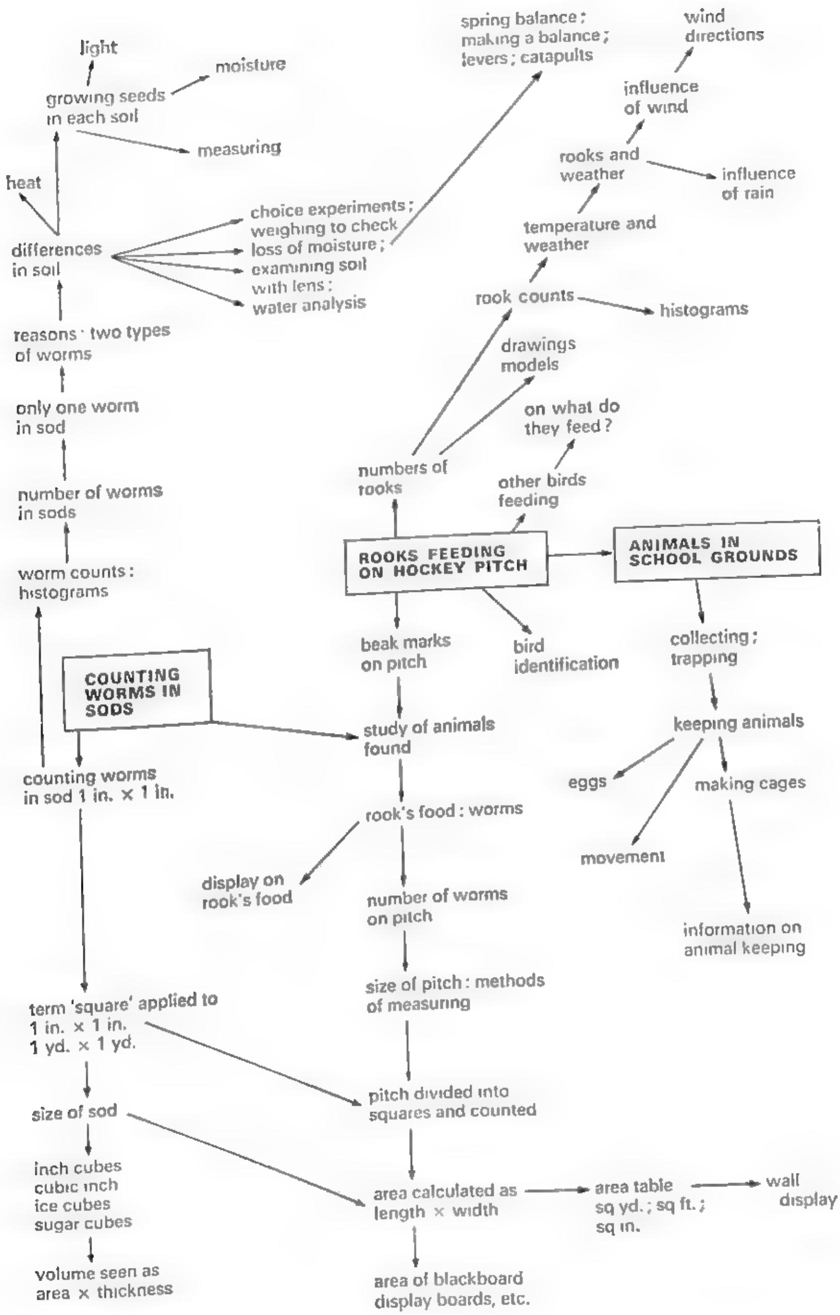
The remark, 'It doesn't contain food,' caused Gary and Norman to conduct experiments in their soil samples with growing seedlings, using mustard and cress.

These two boys went on to study problems involving the importance of light and temperature in germination. Having used a variety of containers, plastic, and earthenware, they had much to think about.

Just before the end of the term, Paul and Peter began to examine the soils with a magnifying glass. They noticed differences in particle size and found that these became most obvious when they shook up water and soil samples in tubes and allowed the particles to settle.

When the pupils first noticed the rooks in the school grounds, their interest centred around the numbers seen and the food they ate. They periodically reported the presence or absence of rooks on the pitches and eventually began to wonder about the variation in number.

After much discussion, a small group, all boys, decided to count the numbers at intervals during the day—but at what intervals? Many suggestions were made: every fifteen minutes, every morning and afternoon, or every one and a half or two hours. Eventually they decided to count once every two hours throughout the school day and organized a rota of counters, each with an elaborate form to complete. They represented the results as block graphs and attempted to correlate the numbers of rooks with variations in weather. This proved difficult, and eventually, much less ambitiously, they began to enquire whether there was a connection with wind direction.



ANIMALS IN SCHOOL GROUNDS
ROOKS FEEDING ON HOCKEY PITCH
COUNTING WORMS IN SODS
collecting; trapping
keeping animals
eggs
making cages
movement
information on animal keeping
numbers of rooks
rook counts
histograms
temperature and weather
rooks and weather
influence of wind
wind directions
influence of rain
drawings models
other birds feeding
on what do they feed?
beak marks on pitch
bird identification
study of animals found
rook's food: worms
display on rook's food
number of worms on pitch
size of pitch: methods of measuring
pitch divided into squares and counted
area calculated as length × width
area table sq yd.; sq ft.; sq in.
wall display
area of blackboard display boards, etc.
counting worms in sod 1 in. × 1 in.
worm counts: histograms
number of worms in sods
only one worm in sod
reasons: two types of worms
differences in soil
heat
growing seeds in each soil
light
moisture
measuring
choice experiments; weighing to check loss of moisture; examining soil with lens; water analysis
spring balance; making a balance; levers; catapults
term 'square' applied to 1 in. × 1 in. 1 yd. × 1 yd.
size of sod
inch cubes cubic inch ice cubes sugar cubes
volume seen as area × thickness

32 Angling

Class	**10-11 years. Unstreamed; ability average and below**
Class number School roll	34 boys and girls 280
Terms	Autumn and part of spring
Building	A typical city Board School built in 1873
Classroom	Old, with high windows on one side. Twin iron-framed desks with sloping tops. Not much room for moving around. Another room is available with good working facilities.
School environment	Paved yards, shared with infant department. The school is in one of a maze of little streets off a main arterial road through the city. Many families have moved out to new housing estates.
Local setting	North-west England. Large seaport. Massive rehousing. Park nearby.

The class had been surveying in a nearby park. On the way back to school, the teacher discovered that the majority of the children, both boys and girls, were keen anglers. They were enthusiastic at his suggestion that they might do a project on fish.

The children discussed possible lines of investigation and decided what they wanted to do. They formed groups according to their interests. Four of the girls were undecided at first. They wanted to do 'something about water' but did not know what. After some discussion they decided to try to find out about the city's water supply.

One group heard that some anglers would be netting fish in one lake to stock another. They went along one Saturday afternoon to watch. They saw a number of different kinds of fish and set up aquaria for living fish in school. They studied some fresh (and frozen) specimens, which the Zoology Department of the University supplied. Some of the fish they recognized; others they identified by consulting books, pictures, and written descriptions. They made many drawings and paintings, and set out an attractive diorama in a large (cracked) tank in the school corridor. They also wanted to make plaster casts of fish, but experiments with casting were not very successful.

A small pike which was brought in was estimated by the children to weigh about $1\frac{1}{2}$ lb. Stanley said he had been with his father when a 6 lb. pike had been caught, and another boy asked, 'How long was it?' The children then discussed weight and length, and

the teacher suggested that they might find out if there was a correlation between them.

One of the tanks contained four goldfish of different lengths, and the boys started thinking how they could get the necessary measurements. It was some days before they suggested weighing each of the fish. They did this, and measured the length of each fish by putting it in a small oblong plastic container in which it could not turn round. They recorded their results in a block graph. They also weighed and measured a number of herring and tried to find out the age of the fish by examining their scales under the microscope.

The teacher asked about the breaking points of different fishing lines: did they correspond exactly to what was printed on the spools? were the more expensive ones more reliable? The children worked out how they could test the lines, and found considerable variation between their findings and those of the makers.

After Christmas, in spite of weather conditions, the group made several visits to a lake. They took samples of the water to find out what the fish feed on. At first they discovered very little evidence of life. Then, on 21st February, they had a successful catch of water-boatmen, shrimps, and various insect larvae. Also, much to his surprise, Stanley caught a tench with his net.

On 8th March the children reported that the lake was 'teeming with life'. They caught carp, roach, and tench, and brought back netted samples for identification. The children set up a new tank for the fish and tried to find out what other animals lived in the lake. They realized that they must know what each of their fish ate if they were to keep them all alive for study.

Another group decided to try to find out which was the best shape for moving through water, and for this, they borrowed a water tray from the infants. Using the same amount of Plasticine for each shape, they made a cube, a sphere, a rectangle, a cigar shape, and a dumb-bell shape, and pulled them through the water. At first they pulled them with their hands, but quickly realized that their fingers were causing additional disturbance in the water, and used string instead. They can be seen in figure 69. When asked which shape they thought would be the best, they said, 'The sphere, because the water will slip round it.' Each boy, in turn, pulled several different shapes and all agreed that the cigar shape was the 'easiest' to pull and made the least disturbance in the water. The boy who had made a cube changed it to a fish shape. He was delighted when it 'beat' the others.

In an attempt to measure the 'pull', the group tried a spring balance, but it was not sufficiently sensitive: the pupils realized the need for some means of measurement and left it at that for the time being. In recording

FIG. 69. Discovering the best shapes for movements through water.

this experiment, two boys, Eric and Robert, showed a much higher standard of written English than anything they had achieved before: they were writing about first-hand experience.

An attempt to make a 'perfect streamlined shape' in papier-mâché was not altogether successful as the object had a flat base. The boys who made it seemed to be satisfied, but they realized that it could have been built around a wire support and suspended.

The question of streamlining was followed up in relation to speed of movement on land and in the air, and modern trends in design were discussed. Vehicles were timed over a measured distance (one-tenth of a mile) using a stopwatch. The children wanted to time themselves over a given distance—running, walking, and hopping. Ronald Dougan suggested finding out about the speed of falling objects but this project was not investigated until later.

The keen swimmers wanted to time the different swimming strokes over a given distance to find out which was the most effective. They did this at the swimming baths, making a graph of the results and comparing them with local Schools Championship records. They also collected the relevant British Junior and Olympic records.

They experimented with flippers to find out what difference these made to the efficiency of the various strokes. This group was also very interested in skin-diving, the problems that water pressure gives divers and equipment manufacturers, and the relative depths to which man can go, using various devices. As a result of their reading, they experimented on water pressure, especially in relation to depth. The weight of water interested them, and they worked out the volume of water in the swimming bath—3 ft. at one end and 6 ft. at the other. After that they tested the floating ability of various materials and began to discuss density.

A small group of children, watching some sticklebacks which were sharing a tank with an axolotl, noticed that they came to the surface at frequent intervals. One child said: 'They are coming up for air. Do fish usually breathe air?' They went off to watch fish in other tanks, but these did not come to the surface. The children explained the behaviour of the sticklebacks by saying, 'The water is dirty and doesn't have enough air in it, because the axolotl stays below and uses it all.'

They examined fish heads, from a fishmonger's bucket, and discovered the way through the mouth to the gill slits. They examined the gills in detail, even isolating a filament and seeing what it was like under the microscope.

Living fish were closely and intently observed by the children and they found out how the fins were used in movement and how the mouth and gill covers worked.

Lorraine borrowed a book on fish from the public library and started to make her own book, writing out with great care the information she collected. One item about the surface area of water and the number and size of fish that could be kept in a tank, started her working out how many fish, of varying lengths, could be kept in the classroom aquarium. While she was doing this she noticed that the level of the water had dropped exactly one inch in a week. She worked out the volume of water that had evaporated and then made a hollow inch cube from Plasticine, 'baled' out an inch depth of water from the tank, and compared the results.

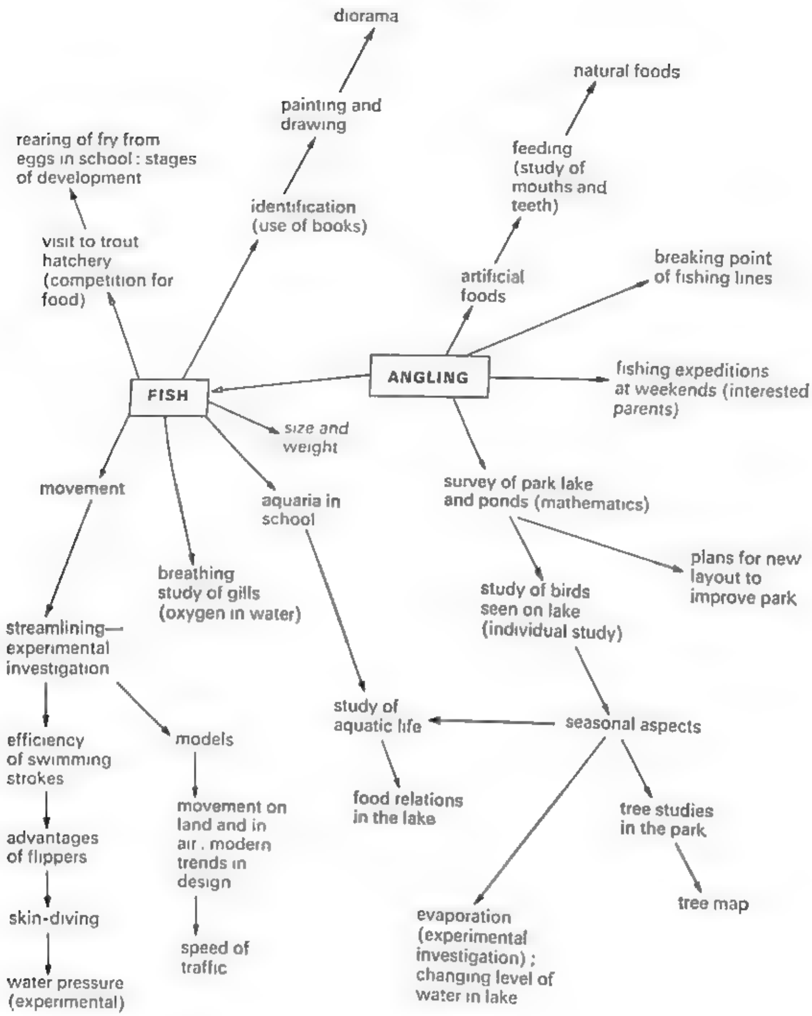
She went on to find out the weight of the water that had evaporated. During the following week, less water evaporated from the tank, and Lorraine set up some experiments to find out if the size of the surface of water made any difference to the evaporation rate. She used the same volume of water in different containers and, because it was near the end of term, put them on the radiator to 'speed them up'!

The four girls who started on a study of the city's water supply did not get very far. They visited the offices of the Water Board and obtained a supply of literature. They wanted to see filter beds (having done some filtering experiments last year), but it was not possible

to obtain permission for junior children to go. Quite soon they joined Lorraine in her practical investigation of evaporation, and the following term became interested in the trees in the park. They paired up with friends and started a seasonal study of a chosen tree. They also planned to make a tree map of the park, and to design one or two 'improvements' to the layout of the park rose garden.

In February the class visited a trout hatchery and saw all stages in growth from egg to a fish of 3 or 4 lb. As they watched the fish being fed, the children realized how great the competition was and how the stronger, quicker fish got the food every time. They were told that in these artificial ponds, it was necessary to net out the smaller fish into another pond or they would die of starvation. A discussion about what happened in the river followed, and the children thought that the smaller fish had a better chance of escape and that the food was 'more scattered'. In school, a group of children set up a small hatchery and they succeeded in rearing some fry and following the various stages in development.

This work began in October, and continued during the first part of the Spring Term, until disrupted by preparatory tests and the 11+ examination. During the last two weeks of term, the children picked up the threads and discussed future plans.



diorama
painting and drawing
identification (use of books)
rearing of fry from eggs in school: stages of development
visit to trout hatchery (competition for food)
natural foods
feeding (study of mouths and teeth)
artificial foods
breaking point of fishing lines
FISH
ANGLING
fishing expeditions at weekends (interested parents)
size and weight
movement
aquaria in school
survey of park lake and ponds (mathematics)
breathing study of gills (oxygen in water)
plans for new layout to improve park
study of birds seen on lake (individual study)
streamlining—experimental investigation
efficiency of swimming strokes
models
study of aquatic life
seasonal aspects
food relations in the lake
movement on land and in air. modern trends in design
tree studies in the park
advantages of flippers
skin-diving
speed of traffic
tree map
evaporation (experimental investigation); changing level of water in lake
water pressure (experimental)

33 *A farm visit*

Class	**10-11 years. Full range of ability**
Class number School roll	36 boys and girls 545
Term	Autumn
Building	Completed in 1958
Classroom	*Good working and display facilities; storage space in store* room. Horizontal working space at the back of the room. Additional tables at the side of the room.
School environment	School situated in its own grounds, laid out in lawns and areas of grass with trees planted. Hedgerow, woodland, streams, and farmland easily reached.
Local setting	Northern Ireland. Suburb of large industrial city.

The pupils went to a farm near the school. On the ten acres there were hens, pigs, and cattle for fattening. The farmer's wife showed the pupils round the farm, talked about things of interest, and answered questions. When asked why there were no sheep, she said that it was because there were so many dogs on the estate. This came as a surprise to most of the children.

When they returned to the school, the children discussed and asked questions about what they had seen.

Drawings were made of various breeds of animals, and books and pictures were collected. Those children who owned dogs were very willing to talk about their pets' behaviour and the foods they liked, and one girl said she had seen a television advertisement showing dogs choosing one brand of dog food from a variety. The children were interested in this idea and decided to carry out their own test.

Three children brought their dogs to school and the TV experiment was repeated. A great deal of thought was involved in designing this test. The pupils thought about the type and colour of the food containers to be used, the spacing of the dishes, the distance the dogs should be from the sample, and the question of whether the dog should have a sniff of each food before it was allowed to eat. Only one dog chose the advertised food. The experiment was repeated, and this time not one of the three dogs chose the advertised food.

The children were interested in the results of the test and wrote to the manufacturers about it. The manufacturers replied that they did not understand why the dogs did not choose the food, but suggested that maybe

they had not had an opportunity to find out how good it was.

One girl explained how she thought the advertising film was made. She believed that the cameraman kept on filming the dog until he had film showing it going to the advertised food.

Interest now returned to the dogs on the housing estate near the school. A group of five found out how many children in the class had dogs, and this made them decide to find out how many dogs there were on the whole of the estate. One girl suggested that each member of the group should draw up a questionnaire to be filled in by householders. From the five questionnaires, a final draft was made and duplicated.

The questionnaire asked about the breed, age, food, sex, etc. Eighty-six forms were completed, and from these the children worked out the number and ages of dogs of various species. This information was displayed in block graph form.

The manufacturers of the dog food had sent three tins of food. The children proposed to raffle them, but their plans became steadily more ambitious and eventually took shape as a full scale auction, which made about three pounds. They sent the money to the Guide Dogs for the Blind Fund. Interest in blindness now led several children to investigate the ability of other pupils to identify sounds and objects they could not see. Again, they recorded their results in graphical form and made books about the work. Late in the term, Gipsy, one of the dogs in the feeding trials, died, and a full-page obituary appeared on the display board.

While this had been going on, a small group of boys became interested in the variety of spades they saw on the farm; and one of the questions they asked was, 'Why are spades different shapes?'

They collected spades of eight different sizes and shapes, tested these on soil, sand, and stones, and used them for digging, shovelling, and other operations. A table was drawn up to show the shape of each spade and the job it did most effectively.

Each spade was weighed, and the blade and the length of the handle were measured. The amount of soil that each spade could hold was found, the pupils looking for a relationship between this and the weight of the spade. They soon saw that the lightest spade held most soil, and realized that the size of the blade was all important. Calculation of the area of the blade produced problems, as all the spades had a taper. The children used chalk to mark the blade off in inch squares and counted them. In this way they were able to count half squares, and make allowances for smaller parts of one square inch. Block graphs were drawn, showing the weight of the spades, length of the handle, weight of soil that each could carry, and area of blade.

It was while William was lifting a spade laden with soil that he commented on the position of his hands on the handle and the weight of the load. The nearer he put one hand to the blade, the lighter it felt. 'Is it really lighter or does it just feel lighter?' he asked.

Experiments were carried out with the spade, with two bricks as the load on the blade. A spring balance was attached to the handle. The spade was balanced near the blade on the edge of a tea chest, and the force needed to hold the bricks was measured. The point of balance was now moved six inches up the handle and measured again. This was repeated a number of times, and all the group saw and recorded that the further the point of balance was from the blade, the more effort was needed. Further work was now done with a lath of wood and weights, finding the position of two different weights so that the lath stayed in the horizontal position.

At this time they wrote to the Director of the Ulster Folk Museum, telling him of their work and asking for help. The Director arranged a visit, during which the pupils visited a spade mill and saw a spade being made. They had an opportunity to discuss with the spade maker the questions they wanted answered. In the museum the record book of the spade mill dating back to the early 1900s was of great interest, especially

where it gave information on rates of the workers' pay and the variety of spades they made.

One girl, on returning from the farm, had asked this question: 'When you eat an egg, do you eat a hen?' This was greeted with laughter, but she stuck to her point and went on to talk about chicks developing inside eggs. Talk centred around incubators, and several designs were produced, each having straw to 'keep the heat in' and an electric bulb as a heat source. One boy pointed out the need to control the temperature, and suggested using a tropical aquarium thermostat. The teacher produced a bulb, socket, and thermostat and the children attempted to connect them. At this point it was felt that the pupils should be encouraged to experiment with electricity, and that it should be directed to low voltage work. The dangers of mains electricity were pointed out and the suggestion made that when the children had solved the problem using batteries, they might tackle the wiring up for the mains under adult supervision.

The children were keen to try out circuitry problems, so the teacher borrowed a commercial incubator. There was an immediate demand for eggs, and these were bought from the small farm that had been visited. Then they set up the eggs in the incubator, finding out the temperature required from books. The plug on the incubator had to be changed, and there was a good deal of discussion about colours of wires and their positions in the plug. This stimulated some boys to make a collection of plugs and switches and study their construction, and to attempt to use them in low voltage circuits.

The children made various guesses as to the time needed for the chicks to hatch. They turned the eggs each day, and kept the sacking below the eggs wet, keeping a close watch on the thermometer to see that it stayed at 103°F. When the time for hatching had almost arrived, a school holiday occurred, but the pupils insisted on coming in on the second day of the holiday, which was the twenty-first day of incubation. When they lifted the cover off the incubator, they saw that five chicks had hatched, one was about to do so, and the remaining shells were unbroken.

The five chicks were of various colours, two golden and three brown. 'Why are they different colours?' asked one girl. She visited the farm later, and saw the various breeds of hens and cocks.

Some days later, when all hope of successful hatching had passed, the remaining six eggs were opened, and the children kept records of what they saw. There were four chicks dead in the shells, and two eggs which had not been fertilized.

The living chicks were cared for, and the children visited the farm to collect the correct food and learn how to look after them. They made a record of the development of the chicks.

A fortnight later the class decided to send the chickens up to the local farm, and to ring them so that they could be identified. The temperature had now been lowered gradually day by day until it was equal to that of the room.

Some of the children commented on the eggshells and membranes, and one boy copied from a book a detailed picture showing the contents of a fertilized egg.

The thickness of the shell was measured by breaking small pieces and stacking them together. One girl found that fifteen pieces just measured one quarter of an inch, and decided that the shell was one sixtieth of an inch thick.

Comments were made about the strength of eggshells, and one child pointed out that an egg was very hard to break when squeezed along its long axis. The children wondered how much weight it was able to take and offered a flood of suggested designs for egg breakers.

One design was chosen and tests made. Twelve pounds were needed to break one egg when the pressure was applied on the long axis, while only four pounds broke another when it was placed 'sideways'.

The children tried to think why this should be, discussing the way eggs are packed for transport, and how to break an egg for frying.

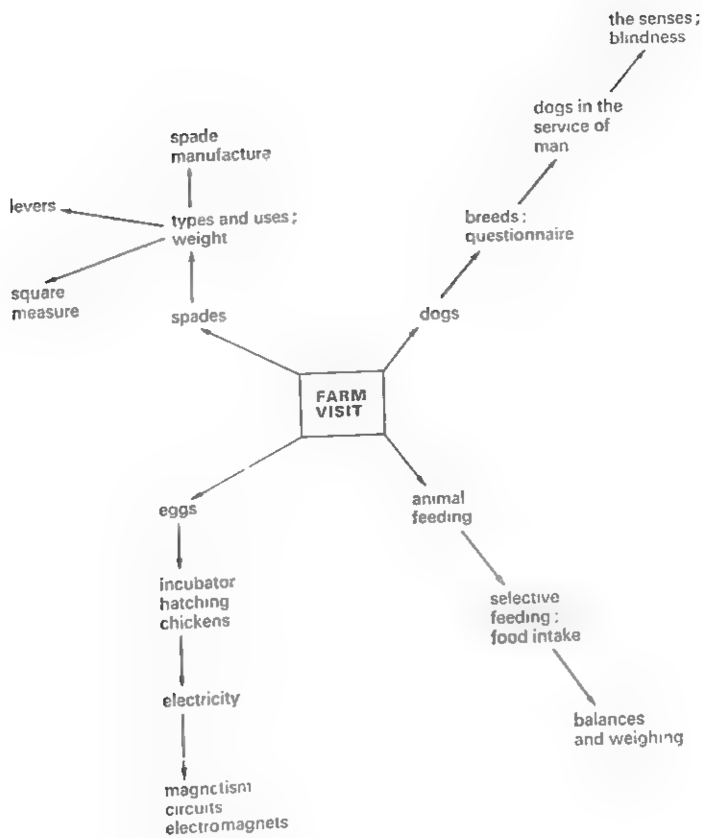
They measured eggs, and noted the various shapes. The teacher told them that the shape of the pointed end of the egg was a parabola. They looked for these shapes at school and at home, and found most of them were reflectors behind lamps. One boy worked out the function of the parabolic reflector by using a torch, and stated that this shape made the light come into a beam. Without the reflector the light 'spread out'.

Experimentation with electricity continued throughout the term, with circuits using varying numbers of bulbs, and switches of various kinds. Switches were improvised, and a two-way switch made and used in wiring up a doll's house.

An electric bell was wired into a circuit with a bell push. By chance, a small plotting compass was lying beside the bell, and when this rang a child noticed that the compass needle was deflected. This started an investigation into magnets and how to make a magnet, using electricity. Success finally came, and a circuit was set up. These magnets the pupils called electric-magnets. They made a crane in Meccano, and fitted an electromagnet to it.

A variety of applications of the knowledge gained stimulated some children to produce a burglar alarm for fitting to a door, others to make a fire alarm that worked by having a strip of lead which, when heated, would bend, touch a contact, and so switch on a light and sound a bell. Another group made a 'Morse blinker'. In each case the idea came from the children, who planned and made the equipment. Booklets were produced with these titles: 'What I found out'; 'Hints for Electricians'; 'Magnets and Magnetism'; 'Electric Magnets'; and 'Fire and Burglar Alarms'.

Children in another group were interested in foodstuffs used on the farm, and made a collection which they put on display. The children also kept a hamster, and made observations on its method of feeding. They also kept records of the weights of food eaten, and the weight of the hamster.


the senses; blindness
dogs in the service of man
spade manufacture
levers
types and uses; weight
breeds: questionnaire
square measure
spades
dogs
FARM VISIT
eggs
animal feeding
incubator hatching chickens
selective feeding: food intake
electricity
balances and weighing
magnetism circuits electromagnets

34 A riverside

Class	**10-11 years. Full range of ability**
Class number School roll	44 boys and girls 160
Term	Autumn
Building	Built just over 100 years ago. Central hall. Classrooms separated by glazed partitions.
Classroom	Class became too large for usual room, so had to be moved to room attached to school which was formerly a small museum. Modern desks and chairs. One electric point.
School environment	Elevated position at the edge of a large village. Serving village and surrounding agricultural area.
Local setting	North-east England. Bridging point over the river. Local industry: agriculture, quarrying, manufacture of drain pipes using local clay.

The teacher and children discussed their programme for the autumn term and decided to study the riverside. During the first visit they looked for anything interesting, and a number of children collected pebbles while a few tried to catch minnows and other small water creatures. Two boys found a place where the bank was crumbling, and, noticing the layers of sand and soil, they began to dig away earth to find out what lay underneath. They were wondering if they might eventually find water. Some children threw stones into the water, but in spite of the teacher's promptings they showed no interest in the ripples which formed. Tiring of this, they began to look for water creatures.

Those children who had no definite ideas on what to do looked to the teacher for guidance, and seeing him collecting plants, they did the same, bringing their finds for him to see. Most of the children moved around a good deal and collected an assortment of material.

When they returned to the classroom they began to examine the material they had collected. A few children had collected similar objects and they came together in small groups, but the majority worked individually. Susan was one of these. She had found some willow galls, which she tried to identify with the help of a reference book. She made a cage for them from a jam jar, a piece of paper, and a rubber band as shown in figure 70, and having done this, she realized that when the gallflies emerged they might drown, so she modified it as in figure 71.

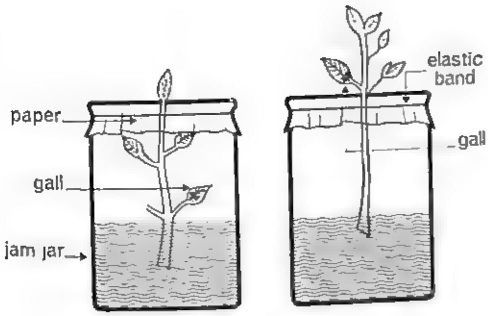


FIG. 70 (*left*). Susan's first container for the willow galls.
FIG. 71 (*right*). Susan's container, modified.

After lunch, Susan said: 'I've been thinking about the cage all lunch time. It needs something over it or the gallflies will fly away.' She found a plastic bag, made a few pin holes in it, then fastened it over the plant. This satisfied her for a few days, but she was soon producing improved designs.

One day she noticed bubbles forming on the sides of the jam jar, under the water, and wanted to know if these were made by the twig. When the teacher asked her how she could find out, she said that she could get another jar of water and cover it with paper in exactly the same way, but leave out the twig. She did this, and discovered that the bubbles came from the water and not from the twig.

A group of children were studying river pebbles. They thought that their shape must have been caused by the water rubbing the rough edges away, and carried out experiments to see if this was correct.

Some children ground pieces of stone together to make three different kinds of soil. To reassure themselves that their soil was real, they decided to see if cress seeds would grow in it. When the seeds germinated and grew, the children were triumphant, but when the shoots died after a few days an inquest was held and they decided to see if this would happen in garden soil. Seeds were sown in garden soil and in each of the other soils, and the results were compared. At the teacher's suggestion, some seeds were also sown in a tin lid containing tap water and they grew almost as well as those in the soil which the children had made from rock. Eventually they decided that their soils were short of plant food, so they added fertilizer and again grew cress in them. Finally, they read that plants feed on humus formed from decaying organic matter, so they grew cress in their soil, and when it died mixed the dead plants into the soil. They intended to repeat this several times, noting how long each lot of seedlings grew before dying. But it became tedious, interest waned, and no conclusion was reached.

The children also identified many of the pebbles and learned to use dilute acid as a test for limestone. This developed into an interest in minerals and rock types.

Soil samples were collected from many places and compared. Children who went away for the weekend brought back samples which were different in colour and texture, and soon sought explanations. After trying to separate the large and small particles in a soil sample, first with a pin, and then by blowing, the children noticed how the river sorted particles when it was in flood. Thus they arrived at the traditional method of water separation.

A second group was interested in the animals they had found. They set up aquaria for the water creatures and used plastic boxes to house the land animals. They observed a great deal, and occasionally experimented. Two girls worked out the speed of their beetle in miles per hour. They watched spiders spinning webs, and tried to get one to spin a perfect orb by providing different frameworks to which it might attach its web. They introduced two spiders into one cage to see how they reacted to each other. Also, they sought a way of collecting and preserving webs and, in doing so, discovered a good way to find them. This followed a boy's observation that all the webs in a hedgerow were visible on damp, misty mornings. The children sprayed the hedge with a fine spray of water and could then see all the webs. After much experimentation,

they decided that the best way to collect a web was to dust it with white chalk dust so that it showed clearly, put a ring of transparent glue on a piece of black paper and press it against the web, and then cut the threads which held the web to its supports. Once collected, the webs were covered in self-adhesive, transparent plastic sheeting, to keep them in good condition.

The children quickly learned to distinguish between insects and spiders and to recognize the main characteristics of each. They were particularly interested in their foods and feeding habits. Many observations which were made by individuals were never recorded and the teacher did not insist that they should be, believing that records should only be made when they had a real purpose to serve. Sometimes the children made sketches which seemed to help them to understand what they saw. As the teacher was clearing away one evening, he found a life-like drawing of a fish lying on the aquarium cover. Someone had looked very closely, drawn what he had seen, then gone away satisfied.

A small group of children studied the bridge. They found masons' marks on the stones, referred to books to find out why they were used, and in doing so, found out about its history. They wanted to make a model of the bridge so they measured it carefully, using a piece of string with a weight on the end to find the height from the water to the parapet. While they were doing this they noticed that the base of each pillar was a hexagon elongated in the direction of the current. They thought it might be directly related to the current, so they cut similar shapes in balsa wood and drew them through the water. They found that it was easier to draw them through the water with the pointed end upstream. This led to discussion about streamlined shapes.

The idea of modelling the bridge was abandoned. Instead, the children started on making a large picture out of cut paper. They searched through a huge pile of magazines for paper which could be used for the bridge, but they could not find any which was the right colour, so decided to make their own. A piece of stone, like that used in the bridge, was brought from the riverside. This was to act as a standard, and they spattered paint onto a large sheet of paper until it matched the stone. Only then would they cut it up and use it. This reflected their increasing attention to detail and their growing respect for accuracy.

Susan showed similar critical awareness when reviewing a wild flower book. She stated: 'The bilberry leaves are not well drawn.' When asked how she knew, she said: 'On Saturday, I picked dozens and matched them against the pictures in the book.'

Having completed the picture of the bridge, the children turned their attention to the traffic which crossed it, and studied traffic flow at various times of day.

They also measured the speed at which the river ran under the bridge. They decided to do this by throwing in a stick and timing it over a measured distance. When the teacher asked, 'What sort of distance?' they replied that it ought to be one which would make it easy to work out the speed of the river. Andrew suggested one hundred yards, but William thought that they might as well use a chain since they had one, and there were exactly eighty in a mile. They marked out a chain and then threw a stick into the water slightly upstream of the marker. When it drifted past the marker they started the stopwatch and then ran to the other marker to stop the watch when the stick reached it. They made three or four trials and took the average time before calculating the speed. On one trial the stick was very difficult to see in the dark choppy water, so they resolved to paint the sticks white next time. Their method of calculating is interesting. They wrote:

1 chain takes	28 seconds
2 chains take	56 seconds
20 chains take	560 seconds
40 chains take	1120 seconds
80 chains take	2240 seconds

and decided the speed was about 2 m.p.h.

Other methods of finding the speed of the river were discussed. Kevin said 'We could push Roy's bike along the bank, keeping in time with a stick that we have thrown in. It has a speedometer on it.' David wanted to make a paddle wheel, hold it in the water, and count the number of times it turned in a minute. He also thought that it might be possible to fix a speedometer onto the paddle wheel, but the others pointed out that this would be too difficult. Unfortunately, the term ended before they could try out these ideas.

From the start, a fourth group had been interested in trees. They collected and compared leaves, twigs, and bark from different trees, and made bark rubbings. They pointed out that bark rubbings were not much use in identifying trees because 'the bark on a young tree is much different to that on an old one of the same sort. A young oak has shiny bark, and an old one has rough. The bark is sometimes different on each side of a tree'. They drew a large map of the river bank and plotted the position of every tree so that they could say in their writing exactly which tree they were referring to.

Soon the group decided that there was so much to do they must limit their study to the Scots pine trees. At first, they guessed the heights of several trees, but when challenged by the teacher, they saw the need to calculate heights more accurately and did this in three different ways, using one to check the accuracy of another. From books, they obtained information about the wood and its uses. They experimented with cones to find out about the conditions under which they opened or closed and related this to seed dispersal. Many winged seeds were dropped from the flat roof of a shed to see how far they would fly in different weather conditions.

John, a farmer's son, noticed that some patches of grass on the river bank were longer and greener than the surrounding grass. He found that these were places where cow dung had been dropped, and wondered why the cattle had not eaten the juicy grass which had grown there. He wrote to a nearby agricultural institute to ask about it, and they explained in their reply that the cows probably avoided the smell, and this was a natural protection against parasites. Following this, he began to study dairy cattle and farm machinery. He made a model of a sheep from wire, paper, and raw wool.

Other children liked his idea and more models appeared. One group made a model of a minnow four feet long. Another group modelled a spider, and continually improved it by adding finer details. The headmaster remarked: 'That spider has been finished every day for three weeks.' One day, for instance, the children had finished it and hung it up when a child said, 'That's not right. A spider has claws on its feet.' A careful examination of a spider showed this was true, so the model was taken down and claws were fixed on. Daily it was modified, yet for a long time it had only six legs. Plate 12 shows the final version.

Towards mid-term, two new branches of study emerged. A group of children began to drop stones off the bridge, expecting large, heavy stones to fall faster than small, light ones. To their surprise, they all seemed to fall at about the same rate, so they tried timing them with a seconds timer. They found this very difficult, because the interval was so short, and asked the teacher to help. He was equally unsuccessful. The children then discussed the problem and produced a solution—dropping two stones together. They did this many times, using stones of different weights, and decided that they all fell at the same rate except for flat stones which 'sort of float in the air'. As a further test, they found two similar cannisters and dropped them from the flat roof of a shed. The cannisters hit the ground together. The children then filled one with sand, and dropped them again. The heavier cannister hit the ground first. This puzzled the group because it contradicted all their previous observations.

By this time they had read all they could find about Galileo and Newton. They felt that their evidence from falling stones confirmed what Galileo had found, but the

cannisters seemed to contradict it. The children all agreed that they needed more evidence and thought that they ought to drop the cannisters from a much greater height to see if they got a different result.

The second new branch of study occurred when Andrew, who was making a model, announced that if he kept on bending a piece of wire, it became hot. Suddenly, the whole class wanted to try, and all kinds of materials were rubbed together to see if they became hot. Gradually the word 'friction' crept into the conversation. Someone remembered reading in an encyclopaedia that primitive peoples made fire by rubbing a stick on a stone. This was tried, but although the children's hands became very hot, there were no signs of fire. They wrote to the publishers, telling them about their efforts and asking for more information, receiving in reply a most helpful letter explaining that primitive people would know exactly which wood and tinder to use, and that their hands would be much tougher than the children's. They thought this was a reasonable answer and were impressed by the difficulties which primitive people must have experienced in making a fire. No wonder it was a disaster if their fire went out!

FIG. 72. A child's stone carving.

The children began to notice friction all around them. One child brought a picture of a rugby scrum and pointed out that friction held it together.

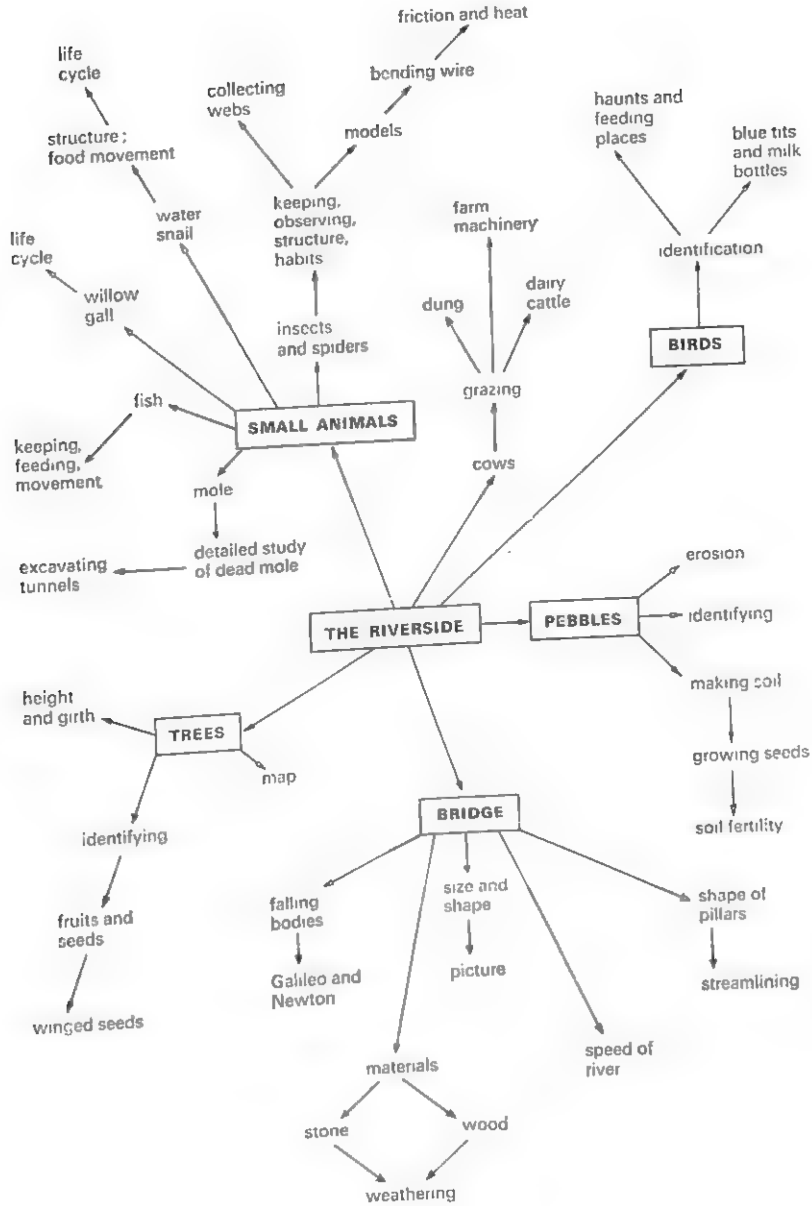
Stone and wood carving arose in a most unexpected way. John wanted to try to make fire by twirling a stick with a bow in a hollow stone. He could not find a suitable stone so he used a hammer and a six-inch nail to cut a hollow in a piece of sandstone. A few days later he picked up a stone on the riverside and transformed it into a head by carving out two eyes and a mouth. Another boy took a few shavings off a piece of driftwood and turned it into a koala bear. Once again, the whole class was keen to try something started by an individual, and most of them did some stone carving. Figure 72 shows John's.

The following conversation was recorded in late November:

WILLIAM: We can't find a spider anywhere. It will be the cold weather. They will hide themselves away.

RAYMOND: Do spiders hibernate?

WILLIAM: The minnows seem to go away in winter.


THE RIVERSIDE
SMALL ANIMALS
insects and spiders
keeping, observing, structure, habits
collecting webs
models
bending wire
friction and heat
water snail
structure; food movement
life cycle
willow gall
life cycle
fish
keeping, feeding, movement
mole
detailed study of dead mole
excavating tunnels
cows
grazing
dung
farm machinery
dairy cattle
BIRDS
identification
haunts and feeding places
blue tits and milk bottles
PEBBLES
erosion
identifying
making soil
growing seeds
soil fertility
TREES
height and girth
map
identifying
fruits and seeds
winged seeds
BRIDGE
falling bodies
Galileo and Newton
size and shape
picture
materials
stone
wood
weathering
speed of river
shape of pillars
streamlining

35 Birds and other things on the playing fields

Class	**10-11 years. Full range of ability**
Class number School roll	39 boys and girls 700
Term	Autumn
Building	Completed in early 1940s
Classroom	Well lighted. Working space cramped. Little storage. Display boards at back and front of room. Dual desks, iron-framed, sloping tops.
School environment	Primary and secondary campus in residential area.
Local setting	Northern Ireland. Industrial city.

When the children visited the playing field, which was being laid out in sports pitches, they noticed a pied wagtail and commented on its movement and its way of feeding. In the playing area the children explored, collected, and questioned freely.

There were many interesting things to be seen. Herring gulls gathered near large pools of rain water, and the children collected flight feathers which they put into polythene bags to take back to school. They also gathered samples of the soil, sand, peat, and stones being used in the preparation of pitches, the clay exposed by bulldozers, and wild flowers growing on an undisturbed bank.

When they returned to the classroom the children examined their collection, sorted it, and discussed their finds. Plants were identified, placed in jam jars, and labelled. There was a good deal of interest in the clay and it was used for making models.

General interest now seemed to be directed along four distinct lines—stones, birds, clay, and plants.

Stones

The collection of stones was grouped according to appearance, the greatest attention being paid to a large piece of broken paving stone. Desmond immediately wanted to make concrete which would look like it, and arrived at school next morning carrying an old saucepan, a spoon, jam jars full of sand and cement, and a pocketful of small stones.

He experimented with various mixes, breaking each sample to see if it looked like the original paving stone, and after trying different kinds and sizes of stones he eventually settled for a mixture of three parts sand, one part cement, and some basalt chips.

The birds the children saw evoked a wealth

of anecdotes, and observations about birds and their behaviour, all of which were later written into a book along with a large selection of chalk drawings. One boy modelled an owl in clay; another did a bas-relief of a jay; and there was a Plasticine model of an eagle.

Birds

Some of the children wanted to identify the birds which visited the school grounds and with the help of *A Field Guide to Birds of Britain and Europe**, they started a list. By the end of term these children had decided to build a bird table and were planning its construction.

Some of the children used the primary feathers of gulls to make quill pens, a task involving considerable trial and error. One girl tried to sharpen her quill with a pencil sharpener and was surprised to find the shaft was hollow. Eventually a parent took a hand, helping his son to make pens from goose quills. The children looked up the history of pens in books, and some of them wrote an account of it, using the goose quills.

At this stage a good many questions were asked:

> 'Why is it that when a duck dives into water it does not come up wet?'
> 'Why does a feather go drip dry?'

Following these questions there were experiments with feathers and water. One child commented 'I think it is because birds have some sort of oil in their wings. If so, where do they get the oil?'

The question, 'Why is one side of a feather always wider than the other?' led some children to examine birds' wings and find that the 'parts' of a feather stuck together, with the smaller edges always facing forward.

At this point there was so much interest in feathers and wing shapes that a study of flight in birds seemed inevitable, but it was to the problem of man's inability to fly that the children eventually turned. They read about the history of flight, made a frieze about flying machines ranging from balloons to the most modern aircraft, and made their own models from corrugated cardboard.

Interest in the local aircraft industry spread to other industries and pupils interviewed friends and relatives about their work.

*Peterson, R., Mountfort, G., and Hollom, P.A.D. (1954) Revised edition. Collins.

Clay

Everyone in the class was interested in clay and made pots and vases, which were left to dry in the classroom before they were painted. Someone wondered about producing a shiny pot and the children experimented with varnish and paint. One boy found that he could polish the clay with a wet handkerchief and it remained shiny when dry.

Some children fired their clay at home by putting it in the fire and David found that models which had not been made from a single piece cracked when fired. By now, various children were making models of heads, faces, and animals, as well as taking impressions of leaves, wood, fabrics, and stone.

One boy made a potter's wheel from bicycle wheels, slats of wood, and lengths of rubber and hardboard; the early model was soon modified to include wheels of different sizes so as to get a more rapid spin. Terry, who powered the wheel, knew where to hold his stick for ease of turning: 'Put it as far out on the wheel as possible.' The children had ready explanations for why one wheel turned faster than the other, and to reverse the direction of spin they put the elastic belt into a figure of eight.

Those children who were interested in moving wheels now began to study gears, which they made of plywood discs with corrugated plastic strips tacked around the perimeter, as figure 73 shows. It was then that Terry discovered that the circumference was a little more than three times the diameter. He had been measuring the amount of plastic needed to go round wheels of various diameters. He made a large chart showing the relationship between diameter and circum-

ference. Some time later, when he found in a book the length of the earth's diameter, he made an estimate of its circumference.

The children studying gears found a relationship between the number of teeth in the gear wheels and the number of revolutions each made, and applied their new-found knowledge to the working of an egg whisk.

By now the clay modellers were making bricks from clay and sand in an effort to reproduce the appearance of those on the local building site. They also measured and weighed bricks, and because there was no suitable scale to hand, Albert made a weighing machine from elastic. He calibrated this simple balance, using ounce weights, and made a graph to show the pattern of stretching.

One child noticed that house-bricks placed in water did not behave like clay in water, and the class then decided to find out if home-made bricks behaved any differently. Accordingly, small clay bricks were fired and put into jam jars of water. The children looked at them periodically and found that one brick remained quite unchanged after three months. One group of children, who were interested in building materials, involved themselves in a study of those used for home building in various parts of the world, and produced a large illustrated book on the subject.

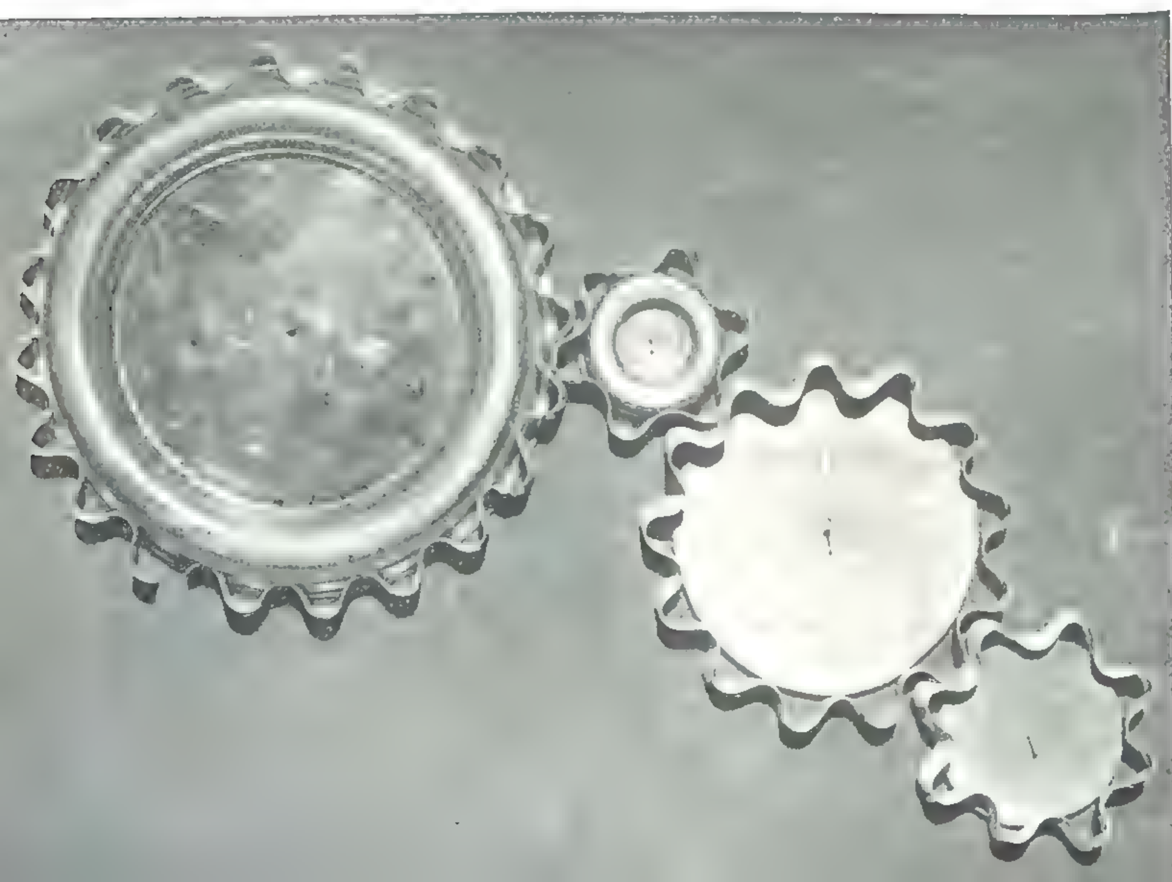
Plants

The girls who brought the plants from the playing fields had a few problems they wanted to solve and devised a series of short term experiments.

For instance, a groundsel plant, complete with roots, was grown in a jam jar of water. Others were grown in pots with soil, and still others in peat, or in sand. The girls were trying to find the best 'soil' for growing groundsel, but their results were inconclusive.

Other children were interested in vegetables

FIG. 73. Gear wheels of plywood and corrugated plastic strips.



and grew them from seeds. One pupil asked, 'What makes a tomato ripen?' To answer this, the children put a green tomato fruit into a cupboard and found that it did not ripen, so they moved it to a window sill and discovered that it turned red on the side facing the light. The next step was to wrap the fruit in brown paper and put it in the cupboard again. After a week they were surprised to find that it had not remained partly green, but was now red all over. One boy summed it up: 'Once the ripening has started, there is nothing we can do about it.'

Meanwhile, others were growing an onion on top of a jam jar of water, observing the root growth, and measuring the shoot each day. The diagram they drew (see figure 74) made an excellent growth graph, and they were even prepared to estimate the growth for Saturday and Sunday so that they could complete it.

The pupils in this class had become very observant, and a physical education lesson had to be stopped while a boy captured an ant and took it to the classroom for further study. Other children brought other specimens of small animals, all of which provoked questioning and discussion.

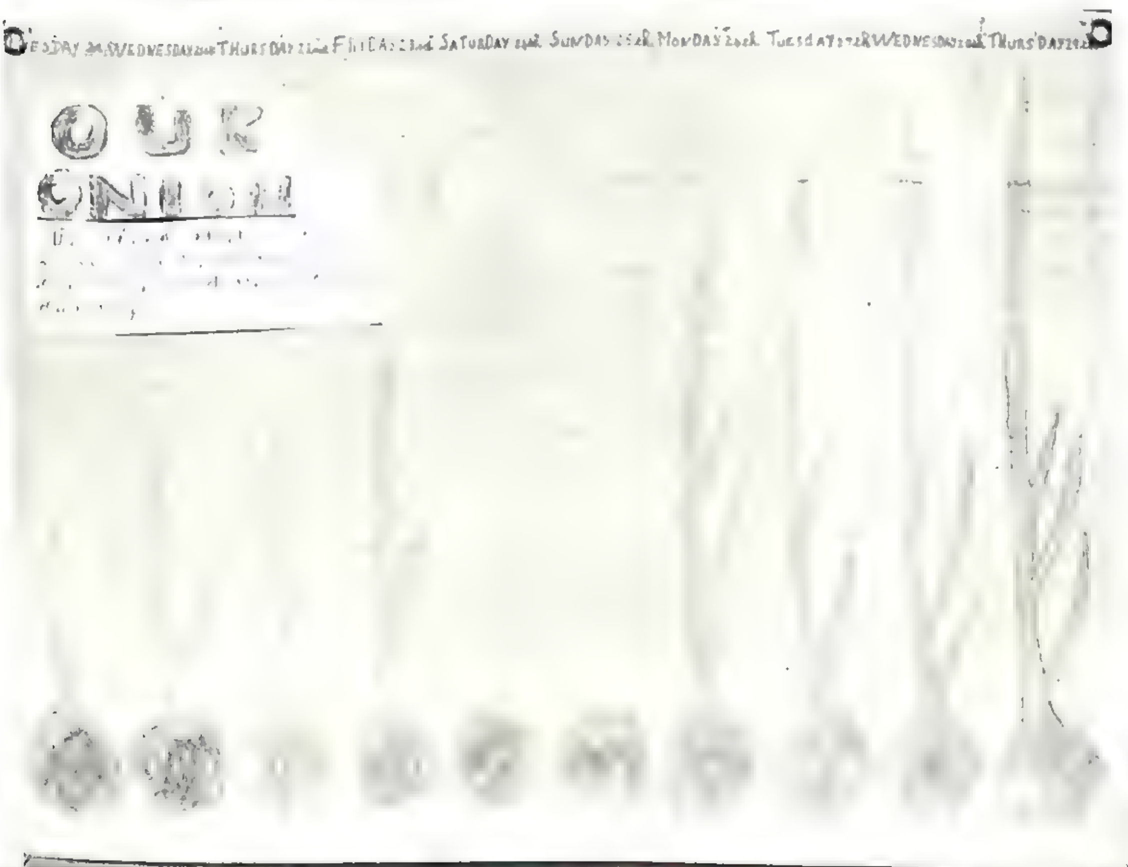
David brought a piece of pummice and was intrigued when it floated on water.

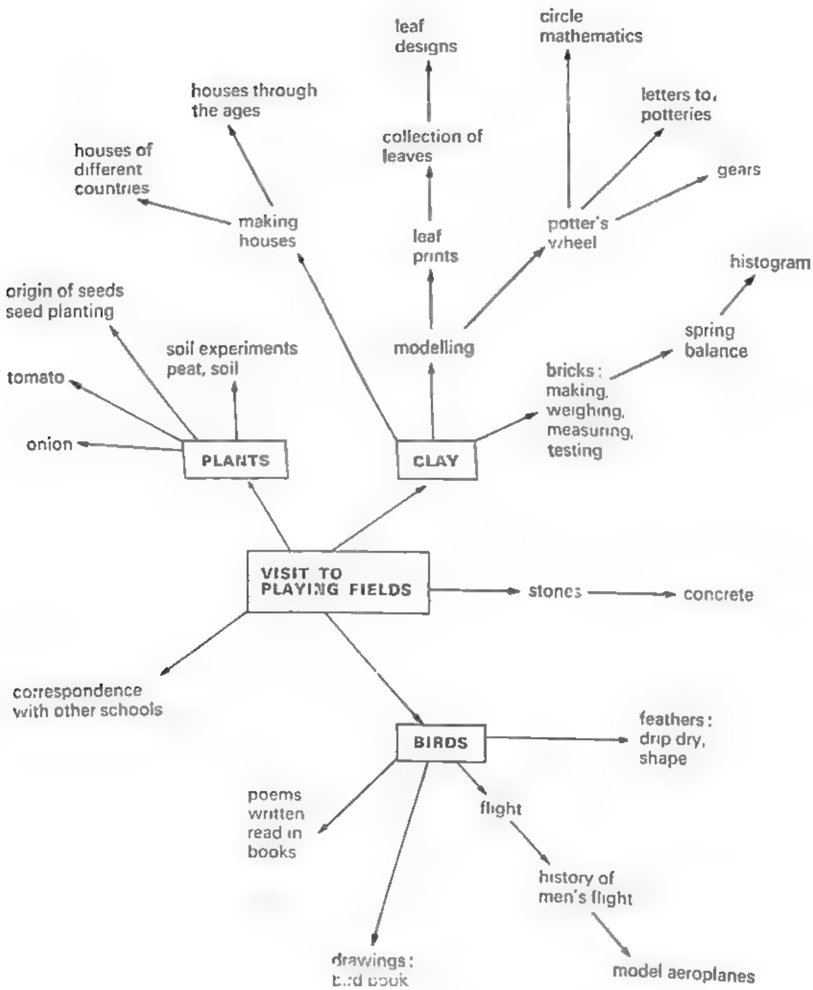
'There must be gas in it.'
'I think there are air bubbles in it.'
'I think it floats because it has a coat around it.'
'I think the stone floats because the air has been trapped in tiny holes.'

A little later, a child said:

'David Bell's stone sunk at last and I know why it sunk. The water has made air holes and gone through to the other side'.

FIG. 74. Daily growth chart of an onion, including estimated results for Saturday and Sunday.




leaf
designs
circle
mathematics
houses through
the ages
letters to
potteries
collection of
leaves
houses of
different
countries
gears
making
houses
leaf
prints
potter's
wheel
histogram
origin of seeds
seed planting
spring
balance
soil experiments
peat, soil
modelling
tomato
bricks:
making,
weighing,
measuring,
testing
onion
PLANTS
CLAY
VISIT TO
PLAYING FIELDS
stones
concrete
correspondence
with other schools
BIRDS
feathers:
drip dry,
shape
poems
written
read in
books
flight
history of
men's flight
drawings:
bird book
model aeroplanes

36 Lead smelting

Class	11-12 years. Full range of ability
Class number School roll	25 boys and girls 84
Term	Summer
Building	Opened in 1960. A sandstone-faced building set on a hillside. Attractive within.
Laboratory	General science. Ideal for 'half-classes'. Single-sided fixed benches with services. Well equipped with traditional laboratory apparatus.
School environment	On the edge of a dale village. The building is surrounded by playing fields and school gardens.
Local setting	North-east England. Upland farming, moorland above. Former lead ore mining and lead smelting dale.

First excursion

The first of the term's science visits for the first year children, arranged during the Easter holidays, was to a small ore mine. Since the mining company restricted visiting school parties to nine pupils and a teacher the chosen few were enthusiasts. The group, all boys, made the visit one evening after school in the first week of term. The mine was always referred to locally as a lead mine, and the boys were surprised to learn when they arrived that only small quantities of lead ore (galena) were now mined and the principal mineral produced was fluorspar. At the mine, head helmets and lamps were issued amidst great excitement.

The trip through the underground workings was an adventure and while it provided some understanding of working conditions below ground, it did not provoke questions or subsequent investigations.

Second excursion

The following week the whole form walked to a galena mine that had ceased production two years previously. The surface remains consisted of derelict buildings, rails, trucks, wood, rubble, and rusty iron. The teacher, aware of the restrictive nature of the conducted tour of the previous week, told the children on arrival that they could explore the site on their own for 30 minutes. Most of the boys were immediately attracted to former mining buildings and machinery. Where floors looked unsafe and equipment seemed dangerous the teacher felt compelled to put the area out of bounds.

The preliminary explorations continued for an hour, twice the time that had been reserved, and when the class was drawn together it was clear that they had not gone beyond the play stage. The teacher then suggested that the children might work in groups and con-

struct something from the materials lying around.

The groups were absorbed by this task for another hour, most of them becoming involved in elementary construction rather than in true creation. Three girls were more ingenious than the others in producing an unexpected and unlikely abstract model from iron bars and wire. A by-product of this activity was that various materials were placed on one side to take back to school.

Before leaving the site the teacher brought the children together and they all examined and discussed the minerals, rocks, and vegetation of the site. The teacher asked questions and probed, to encourage them to explore simple observations and try to explain them.

Third excursion

Some of the boys who had been on the first mine visit asked about the treatment of fluorspar, and the only way to answer them was to make a return trip. The second party consisted of two girls and seven boys of whom six had been in the first.

The fluorspar was treated on the surface so the party did not need to go underground. The children saw the mineral being crushed, washed, sorted, and refined, but as on many industrial visits the noise of machinery made it difficult for them to hear what guides were saying and deterred them from asking questions. Peter impressed the guide with the searching questions he asked at each stage of the processing, but unfortunately, most of the others were unable to hear questions or answers.

Follow-up

The materials collected on each visit were examined and talked about in detail back at school. Microscopes were in frequent use; the children noted differences between rock specimens, as well as the features of lavas, sediments, and altered samples; they classified ores and man-made samples, and related the test for limestone to the laboratory preparation of carbon dioxide which had been dealt with the previous term.

The teacher at this time was troubled by the lack of spontaneity within the class but a turning point was soon to come. This happened when the children considered how galena was smelted. The question itself did not arise suddenly, and it was doubtful who asked it first since it had arisen many times.

The teacher found that informal discussions with the class and with groups produced more and more class participation. In one of them the class was recalling the details of the three visits, mainly for the benefit of two new boys, and he was surprised to see how much the children had remembered. Peter, especially, talked about the chemical nature of minerals with an air of authority.

Smelting

Again the question arose, 'How is lead ore smelted?' It was agreed that great heat was required, possibly greater than that needed to melt metallic lead. Peter was able to tell the class that this was because galena (lead sulphide), contains sulphur as well as lead. Much galena had been collected and the class were intent upon reducing it. How could this be done? Alexander suggested that the fuel should be coke and that the ore would have to be put in a container to prevent it being lost. Then Kathleen added that if a metal tin were used to hold the ore it might melt before the galena. One of the fireclay crucibles that had been brought back from the last visit to the fluorspar mine might prove useful. But a furnace had first to be built, and the children decided to explore the school grounds to see if they could find suitable materials for its construction.

The furnace, illustrated in figure 75, slowly took shape. It is doubtful if it would have had a chimney in the first instance if a 6 ft. pipe had not been discovered in the garden shed. When it was found, Alan said that it would carry away smoke as well as increasing the draught.

Note: the experiments that followed were done under the close supervision of the teacher.

When the furnace was first tried it was soon found that the air supply was inadequate. The children borrowed a car foot pump and this improved matters. But the greatest disadvantage was that it was virtually impossible to recharge the furnace with coke because the hot, heavy lid was difficult to lift.

After several single firings the ore seemed unchanged. A further attempt was made by maintaining the furnace throughout a whole day and attempting to recharge with fuel when necessary. This gave greater and more sustained heat, but still no lead. In the discussion which followed, the children felt that the foot pump had been inadequate and was the cause of the failure. Jane thought they needed bellows. Everyone agreed, and while some would have raided attics or lumber rooms, others thought the village blacksmith might help. The blacksmith suggested that they might be able to salvage the bellows from an old and disused smithy near the school.

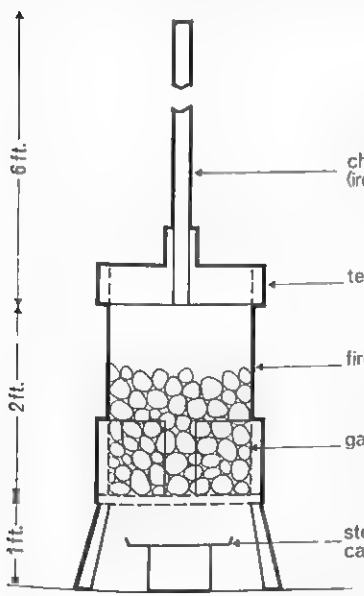


FIG. 75. The furnace, first version, with lid and chimney.

This became an exercise in industrial archaeology, for the huge and ancient hand-operated bellows were in good condition although they had not been used for a long time. The teacher press-ganged three senior boys into helping him trundle the bellows—which he called a 'a monstrosity'—through the village back to school.

Before they used the bellows, Ian thought that they might get some idea of the temperature in the furnace by adding a crucible of zinc which, according to a reference book, would melt at 419°C. They put granulated zinc in a crucible. But instead of putting galena in another some of them thought it should be mixed with the coke and the metal should be collected below the furnace grate. The heavy lid of the furnace and the chimney were dispensed with, and heating began, using the bellows.

The bellows proved very efficient and towards the end of the day some drops of molten metal were seen to fall onto a steel collecting tray below the grate. When cool, this metal was taken to the laboratory. Hopes ran high that it was lead. Indeed, what else could it be? The teacher kept his doubts to himself but a number of the boys said that it did not look like lead. However, the teacher would not let them identify by appearance and, when Peter remarked that the sample was just not heavy enough to be lead, he asked whether there was any difference in the weights of iron, copper, and aluminium pans of the same size. Thus, the children came to consider density for the first time, and when the teacher showed them a book containing a table of densities they soon realized that it could be used as a means of identification.

The sample was found to have a specific gravity of 7·9 and from the table of densities it was clear that the metal was not lead but probably iron. It seemed absurd, and the question was, 'Where did it come from?'

Next day the children discovered the answer, for when the furnace was dismantled they found that the inner surface of the cast iron hearth had melted into an amorphous mass. The zinc had melted into a cone within the

crucible but there was not a sign of lead in the ash, clinker, or remaining coke.

The furnace had not only melted the zinc at 419°C but had also melted iron. The children were astounded to discover from a table of heat constants that cast iron melts between 1,200°C and 1,500°C, and decided that the bellows had been too efficient. After much discussion they decided that the lead ore had probably vaporized. It should be added that the heat from the furnace had also singed the hair and eyebrows of a number of children.

On the next run the class again mixed galena among the coke as well as adding a crucible of it to the furnace. A fairly constant temperature was maintained by reducing the efforts on the bellows. Eventually drops of molten metal were seen to fall onto the tray, and when the teacher removed the crucible and tilted it, a silvery liquid ran out. The children were greatly excited; it seemed certain that lead had been won at long last.

Refining

The metal from the crucible and that from the tray below the furnace contained impurities such as ash and cinders. They were taken to the laboratory for refining.

The method is illustrated in figure 76. The metal top of a large jam jar was bent into the shape of a shallow basin with a long lip, and mounted on a tripod. Four burners were placed above and below the container and the heat was concentrated on the heap of metal added to it. Soon small amounts liquefied and ran into a crucible. Particles that refused to melt and the scum were removed with tongs, and the process continued until all the metal had been purified.

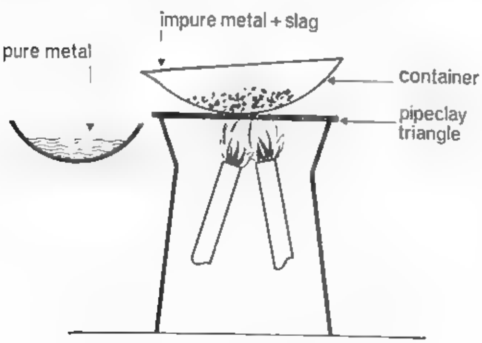


FIG. 76. Refining the metal.

Many of the children were happy to accept the metal as lead, but it was agreed that they should carry out the density test for confirmation.

The question of casting had also arisen, and this was tackled first. Alan suggested that plaster of Paris could be used as a mould. When the plaster was mixed a threepenny piece was used to make a series of impressions. The metal was re-melted and the teacher again insisted, for the sake of safety, upon pouring it into the moulds himself. It solidified to give button-like castings.

When the density of the metallic discs was determined it was found that they were too small to give an accurate reading with the 100 cm³ measuring cylinders available. The group had not previously used a burette or pipette so these were introduced and their functions briefly described.

To the teacher's surprise two of the boys devised a method of determining the density of the discs within five minutes. Alexander and Philip placed a metal disc into a narrow tube of water and withdrew the rise with a pipette. This was added to a burette containing a known quantity of water and that which was added could easily be measured to $\frac{1}{10}$ cm³.

The need for accurate measurement and careful handling of the apparatus became obvious at this stage, since a difference of $\frac{1}{2}$ cm³ could alter the result entirely. After a practice run the following result was obtained:

$$\begin{aligned} \text{weight} &= 13{\cdot}68\ \text{g} \\ \text{volume} &= 1{\cdot}2\ \text{cm}^3 \\ \text{density} &= \frac{13{\cdot}68\ \text{g/cm}^3}{1{\cdot}2} = 11{\cdot}4\ \text{g/cm}^3 \end{aligned}$$

This, a valuable exercise in itself, confirmed that the metal was practically pure lead.

Following this, one of the children thought that other metals could be melted and cast.

From the list of melting points in the book of chemical constants it was clear that aluminium (melting point, 650°C) and zinc (419°C) were two of the more common metals* that could be melted in the laboratory (muffle) furnace which had an upper limit of 1,000°C.

One group began immediately to melt and cast granulated zinc, and another group followed Elizabeth's suggestion that milk bottle tops should be used as a source of aluminium. This group soon expressed surprise at the number of milk bottle caps that were needed to produce a small aluminium disc.

Determination of densities corroborated opinions expressed when comparing weights by hand. The teacher at this point introduced standard laboratory cylinders and cubes of other metals such as copper and alloys like brass.

When the work was beginning to lose momentum the teacher made available other laboratory apparatus. Groups were soon comparing the physical properties of various metals. They measured the different conductivities of heat, expansion, and different rates of expansion. When these investigations were being made, John began to make an individual study of copper that included the physical properties, uses, extraction, and geographical locations of its ores. Other children followed John's example by studying different metals or alloys. These studies called for a wide selection of reference books and the teacher provided as many as possible.

One boy, Iain, who was one of the slower learners, wanted to try and make a casting from solder. He melted this and on pouring it into a metal screw cap from a bottle, was unable to remove the casting. This problem was enough to make Iain realize for the first time that plaster of Paris was being used by his classmates to make moulds. Soon he was casting in plaster of Paris and achieving what he had set out to do. But after much discussion with the teacher Iain agreed to try and find the density of his solder casting. A major obstacle was the mathematics involved but the teacher devoted a great deal of time to Iain and his newly found problem and eventually a figure of 10·8 g/cm³ was obtained. The teacher prepared a short list of densities and Iain was asked to find which was the nearest to that of his solder. He correctly pointed to lead. After more discussion it was decided that the difference in densities between solder and lead might mean that there were things in solder other than lead. With Iain the problem of solder containing lead and having a specific gravity less than lead never arose and a technical dictionary disclosed that soft solder also contains tin.

This tedious but ultimately rewarding exercise took a considerable length of time to accomplish. But when the findings of the term were drawn together Iain had made a contribution of which he was rightly proud.

Lead smelting

To the children smelting was a simple process: they thought galena when melted would naturally yield lead. Peter knew that the ore consisted of lead and sulphur. But the smelting process is not a straight division of the two constituent elements. Those with a knowledge of chemistry or metallurgy know that when galena is heated in a plentiful supply of air it is oxidized and the sulphur is 'burnt off'. The oxide is then reduced by glowing coke to give lead.

$$\text{(a)}\quad \underset{\text{galena}}{2\,PbS} + \underset{\substack{\text{oxygen}\\ \text{(or air)}}}{3\,O_2} \longrightarrow \underset{\text{oxide}}{2\,PbO} + \underset{\text{sulphur dioxide gas}}{2\,SO_2\uparrow}$$

$$\text{(b)}\quad PbO + \underset{\text{coke}}{C} \longrightarrow \underset{\text{lead}}{Pb} + \underset{\text{carbon monoxide gas}}{CO\uparrow}$$

$$2PbO + C \longrightarrow 2Pb + \underset{\text{carbon dioxide gas}}{CO_2\uparrow}$$

The writer remembers some years ago a group of older children from another secon-

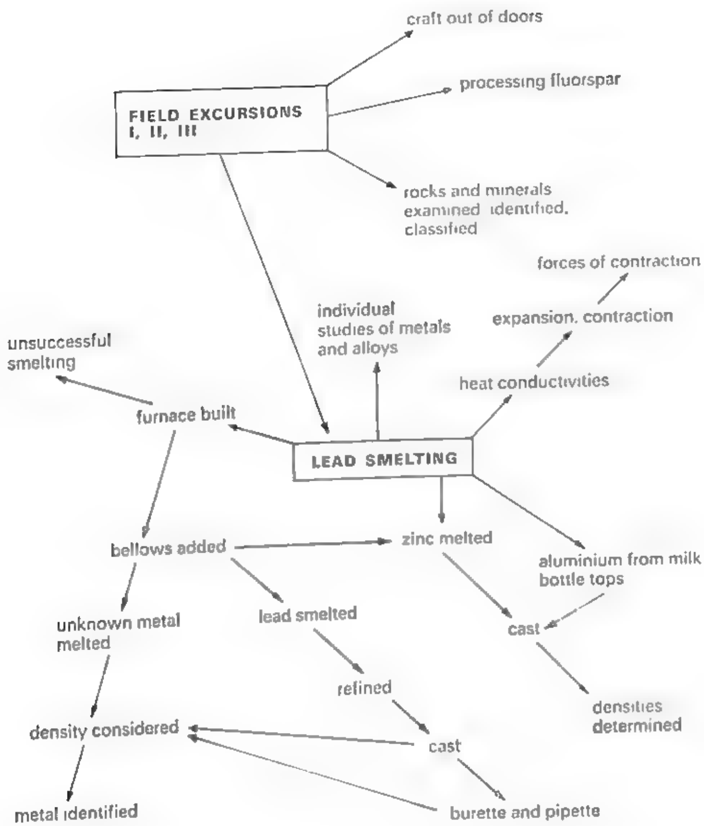
* Also tin (232°C), bismuth (250-269°C) and antimony (650°C). Two well-known alloys, Wood's Metal and Rose's Metal melt at 71°C and 94°C respectively.

dary modern school in the north-east obtaining lead in a different way. During a field week they had collected a large quantity of galena and wished to smelt it on their return to school. After referring to the literature and reading about smelting in a reverberatory furnace they succeeded in obtaining sizeable amounts of metal by roasting ore on a large steel tray in excess of of air, before beating it to a high temperature in an oven-like structure built of bricks.

On roasting, some of the ore had been converted into oxide (PbO) and some into sulphate ($PbSO_4$). The mixture of the three substances when heated to a high temperature in the absence of air gave lead:

$$2PbS + 2PbO + PbSO_4 \longrightarrow 5\,Pb + 3SO_2\uparrow$$

Although the 11- to 12-year olds did not understand underlying chemical principles (and formulae) they seemed in later terms to be growing expert at working their furnace and bellows. A regional and a national newspaper asked at different times if they could cover the smelting process, and on each occasion the output of lead increased considerably.


craft out of doors
processing fluorspar
FIELD EXCURSIONS I, II, III
rocks and minerals examined identified, classified
forces of contraction
individual studies of metals and alloys
expansion, contraction
unsuccessful smelting
heat conductivities
furnace built
LEAD SMELTING
bellows added
zinc melted
aluminium from milk bottle tops
unknown metal melted
lead smelted
cast
refined
densities determined
density considered
cast
metal identified
burette and pipette

37 Field excursions

Class	11-12 years. Full range of ability
Class number School roll	30 boys and girls 105
Term	Spring and summer
Building	Opened in 1960. A sandstone-faced building set on a hillside. Attractive within.
Laboratory	General science. Ideal for 'half-classes'. Single-sided fixed benches with services. Well equipped with traditional laboratory apparatus.
School environment	On the edge of a dale village. The building is surrounded by by playing fields and school gardens.
Local setting	North-east England. Upland farming, moorland above. Former lead ore mining and lead smelting dale.

Towards the end of the spring term a party of ten girls and five boys went to an Expedition Centre to carry out field work. The Centre, maintained by the Youth Service Section of the Local Education Authority, had been a small country school on the moors. Camping equipment was borrowed from the L.E.A. and the boys spent each of the three nights under canvas while the girls slept in the Centre. Conditions were near Arctic each night, but the boys enjoyed the camping and refused to move into the warmth of the Centre's kitchen where their science master slept. A cook who lived nearby prepared each meal and the children willingly undertook many of the domestic chores.

During their stay the children were encouraged to search the moorland and riverside and investigate things which interested them. Follow-up work took place each evening and on their return to school. The number of topics which arose was countless and only those which the children considered in detail will be dealt with. It would be impossible to record every observation that was made and each question that was asked.

First day

After breakfast they visited the riverside which presented so much of interest that the whole day was spent there. Karen's attention was soon drawn to sections of steep slope that appeared to consist of distinct layers. The upper layers were of soft clay while the lower levels were being compressed into shale. A collection of local rocks was started and it was soon found that these were mainly

sandstones and limestone. During the follow-up work, one boy tried to sculpt a vase from a piece of sandstone.

Sheila noticed the great abundance of lichens on trees and walls and wanted to know what they were. That evening she consulted the books that had been brought from school but they were of little help. She read about the existance of lower plant forms, learnt the meaning of symbiosis, and discovered that lichens can be used as dyes. On returning to school Sheila and Karen spent a great deal of time attempting to use lichens and other substances to dye various fabrics. Their success was limited and final colours would undoubtedly have been improved if Violetta Thurstan's valuable work* had been available. But this booklet could only have been introduced towards the end of the investigation, otherwise it would have been tempting to use it as a recipe book.

On the river banks there were many conifers, often planted purposely. Christine and Caroline began to collect specimens from each type and then to note and list the differences between coniferous and deciduous trees. The following term they boiled the needles of a spruce fir and to their surprise obtained a brown liquid. The literature suggested that this was a resinous waste material and after it had been left for some weeks a solid brown mass formed in the solution. This appeared to be a solidified lump of resin.

Anne, who had not been to the Field Centre, but who had helped Christine and Caroline in the early stages of their work, went on to boil shrub leaves in water. A green liquid was obtained and this led to a discussion with the teacher about chlorophyll. The yellow grass beneath a stone was mentioned and Anne was soon seeing a connection between light and chlorophyll production. She needed help in devising a method of demonstrating this, namely, to put plants in a cupboard and compare them with others left in the light. This also indicated the importance of a control experiment.

Second day

The group spent the morning crossing a moor to visit a wood. In spite of walking into an extremely cold wind the children were still able to note the general features and association of vast areas of heather, moss-laden bogs, and outcrops of rock.

Edward thought that the rock exposures had resulted from soil being removed by wind and rain. Later, back at school, he attempted to illustrate this type of erosion. Assisted by Geoffrey, who had not attended the field week, he placed stones in an old enamel bath and covered them with soil. The soil was washed from the rock by 'heavy rain' from a watering can. Dry soil was next removed by 'wind' blown down a tube. When the teacher asked how erosion might be prevented Edward replied that the soil could be held together by the roots of plants, especially by fibrous roots. Following this the boys decided that they would sow grass in the bath and re-enact their forces of erosion once the soil was grass-covered. This became a long-term experiment which was rudely terminated when the caretaker decided that the soil was not wanted and tipped it out into the school garden. It seems likely that the boys may repeat the experiment in the near future.

On the moor Jean wondered how heather over vast tracts continued to grow after being burnt year after year. Later in the term she ignited a sample of heather, recently collected, and while the bulk was charred black there were several green shoots remaining unburnt. Jean concluded that this was the simple answer to her question.

Peat was discovered on the moor top and Judith and Heather decided it was worth investigating. But in the school laboratory they were at a loss to find a use for the peat that they had collected. The teacher, examining the peat, observed that it still seemed wet and wondered how much moisture it contained. The two girls decided to find out but

*Thurstan, V. (1930), *The Use of Vegetable Dyes.* Revised edition. Dryad.

sought advice on how to do this. Having made a start they noticed Jean burning her heather and they decided to do the same with dry peat. When this was done they were left with dark-coloured ash which blackened their hands when touched. It resembled the charcoal used in art. Judith then reasoned that as charcoal is burnt wood, peat must be 'crumbled or decayed woody plant remains which can hold large amounts of moisture.' Judith's grandfather had used peat as a fuel many years ago and he told how peat was cut and stacked. To illustrate this historical information Heather borrowed a peat cutting tool from a local farmer and this was displayed as centrepiece in the 'peat report'.

In the wood the children discovered conifers that they had not encountered the previous day. Each variety was identified, the cone's function discussed, and the elegant seeds of the spruce examined.

While in the wood Kevin found some large bracket fungi and in the discussion which followed* most of the group were surprised to hear that such fungi are not dead material. Fungi and flowering plants were compared and this led Richard at a later date to try and find out why fungi do not need to be green. Ann was able to help with her findings about chlorophyll and Richard, observing the firm adherence of fungi to trees, deduced that the fungi gained nutriment from a host that could be living or non-living.

Third and fourth days

It was decided at breakfast on the third day that the riverside offered more protection from the cold wind that was still blowing. Once the river was reached the group walked in the opposite direction to that taken on the first day. When the teacher asked which direction they were moving in, not one child was certain of the answer. But it was early and with the sun visible it only took a short time to deduce the points of north and south.

A range of materials was collected, including two rodent skulls. These finds offered an attractive topic to be pursued and Peter and Kevin claimed the skulls on returning to school. The large collection of skulls at school was used to compare dental arrangements with diet and general habits of the birds and animals from which the skulls had come. The skulls that had been found were soon labelled 'rabbit'.

Numerous ferns growing from walls were examined and questions arose about the brown withered marks on the backs of fronds. Since they had liberated their contents it seemed difficult to realize that they had contained spore bodies. That evening the children sought help from some of the books that had been brought from school. The fourth day was cold and wet and the party worked near to the Centre or again at the riverside. As on the previous day most of the time was devoted to collecting and observing.

Follow-up not dealt with above

On return to school it was necessary to incorporate the fifteen in the class who had not gone to the Expedition Centre. Initially the class was divided into pairs, linking a child who had been to the Centre with one who had not. Soon many of the pairs were finding difficulty in initiating or sustaining investigations. To cater for these pupils the teacher encouraged a 'central investigation' to develop. This began with an examination of the various soil samples that had been collected by the riverside, on the moor, and in the wood. An informal discussion included many suggestions as to how they could determine some of the properties of the soils. These suggestions were summarized on the blackboard by the teacher; the groups selected those which they wished to investigate and began devising ways of finding answers. The teacher gave no help at this stage unless it was clear that a group was making no progress at all.

* The wood afforded shelter from the wind that the moor did not. Thus the children wanted to stop and discuss their finds in the wood much more than they had when crossing the moor.

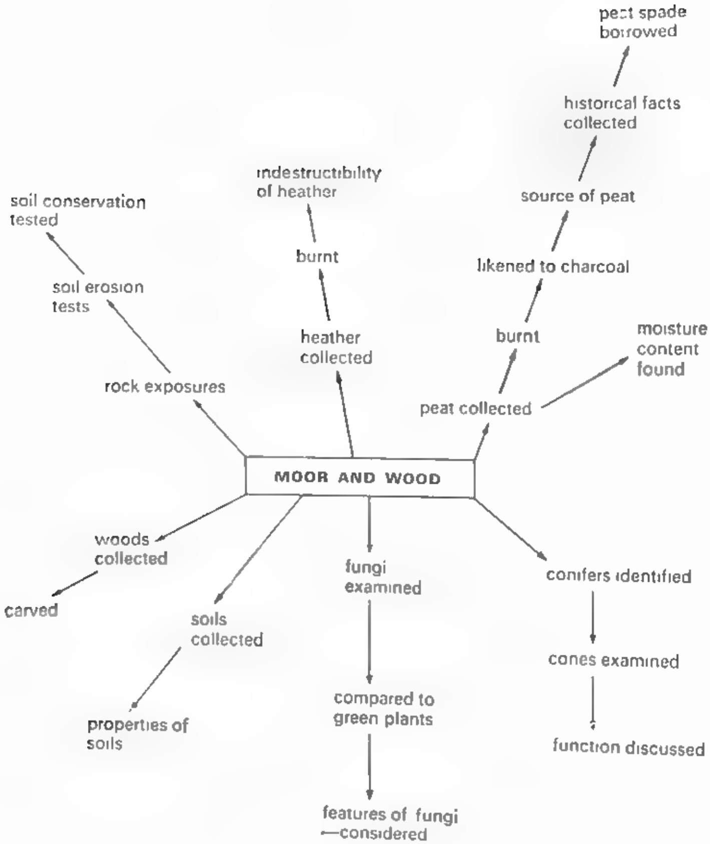
There had been some duplication of work so this allowed comparisons to be made. Finally, the results were collected verbally and summarized on the blackboard:

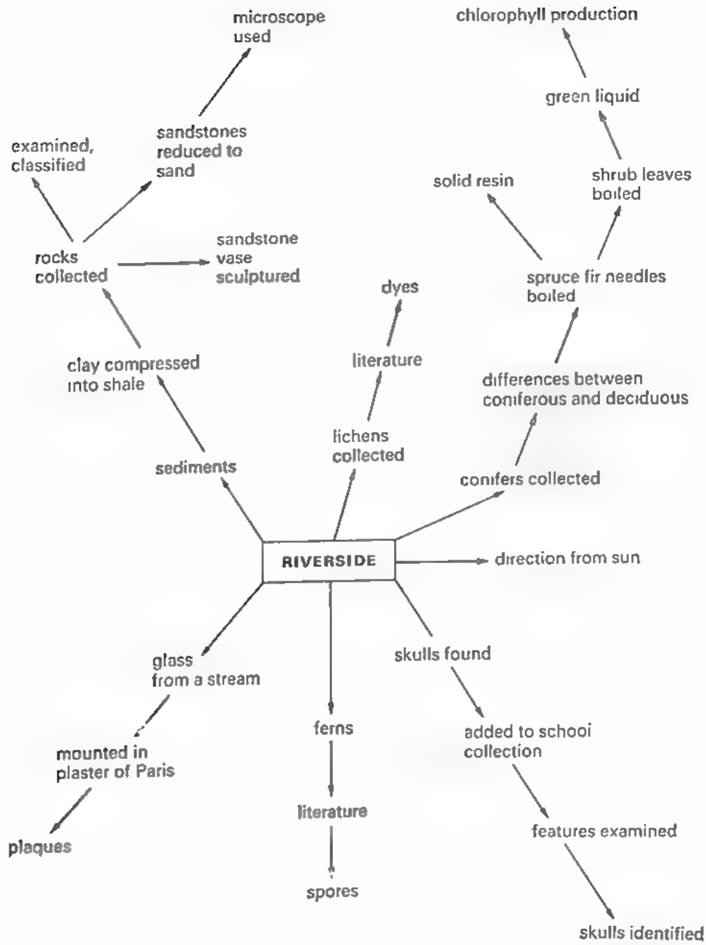
1 Sand particles look very coarse under the microscope.
2 Clay particles look very fine under the microscope.
3 Sand allows water to pass through it quickly.
4 Clay allows water to pass through it slowly.
5 Lime added to a clay suspension causes it to clear.*
6 Sand contains no water.
7 Sandstone breaks into ordinary sand grains.
8 Sand grains can resemble glass.
9 Fossils in limestone indicate the existence of seawater conditions when the rocks were formed.

* Textbooks had provided help.

Materials that had been collected out of doors were used in several non-scientific ways. Two boys began carving the many samples of wood that had been brought back to school, and were soon showing a high degree of skill. Another two, who were among the slower learners, produced several decorative plaques by setting pieces of coloured glass—that had edges rounded in a stream—in plaster of Paris.

A new 'central investigation' dealing with fungi moulds developed from the work already done on fungi. This continued alongside individual and group studies until the end of the summer term.


MOOR AND WOOD
rock exposures
soil erosion tests
soil conservation tested
heather collected
burnt
indestructibility of heather
peat collected
burnt
likened to charcoal
source of peat
historical facts collected
peat spade borrowed
moisture content found
woods collected
carved
soils collected
properties of soils
fungi examined
compared to green plants
features of fungi —considered
conifers identified
cones examined
function discussed


microscope used
chlorophyll production
green liquid
examined, classified
sandstones reduced to sand
solid resin
shrub leaves boiled
rocks collected
sandstone vase sculptured
dyes
spruce fir needles boiled
clay compressed into shale
literature
differences between coniferous and deciduous
lichens collected
sediments
conifers collected
RIVERSIDE
direction from sun
glass from a stream
skulls found
ferns
mounted in plaster of Paris
added to school collection
literature
plaques
features examined
spores
skulls identified

38 Felling a tree

Class	**12-13 years. 3rd of 4 streams**
Class number School roll	32 boys and girls 550
Term	Summer
Building	Built in 1955. Two floors, each served by central corridors. Pleasant throughout.
Laboratory	Traditional design. Single-sided benches with standard services.
School environment	A campus site containing two secondary modern schools and one grammar school. The three buildings are surrounded by gardens and playing fields. The site is close to the line of Hadrian's Wall.
Local setting	North-east England. On the fringe of a large industrial city. Heavy industries, and countryside nearby.

Form 2C were having a science lesson when a party of workmen arrived in the school grounds to fell a large sycamore tree which had become dangerous. The class went out to see them start work. Because the tree was at the side of a busy main road the children were soon speculating as to the way the tree would be cut to prevent it falling onto the road. They estimated its height, its shape, and the effect the prevailing wind seemed to have had upon it. One group followed up the teacher's suggestion that its height could be determined accurately.

A second set of questions arose when the immediate concern of getting the tree down safely had passed. The children were interested in the name of the tree, its age, the reason for felling it, and other nearby trees and ways of identifying them. Anyone who wished could visit the site of operations during normal school breaks in the next few days but by the time the form went together again the tree was down, its side branches had been removed, and the whole had been cut into movable logs.

By then the reason for declaring the tree dangerous was obvious, for part of it was hollow. A group of children collected rotten material from the inner surface to examine in the laboratory. They discovered many insects and spent much time identifying these while trying also to find whether any of the insects had assisted decay. This group had enjoyed hacking out the inside of a hollow log and

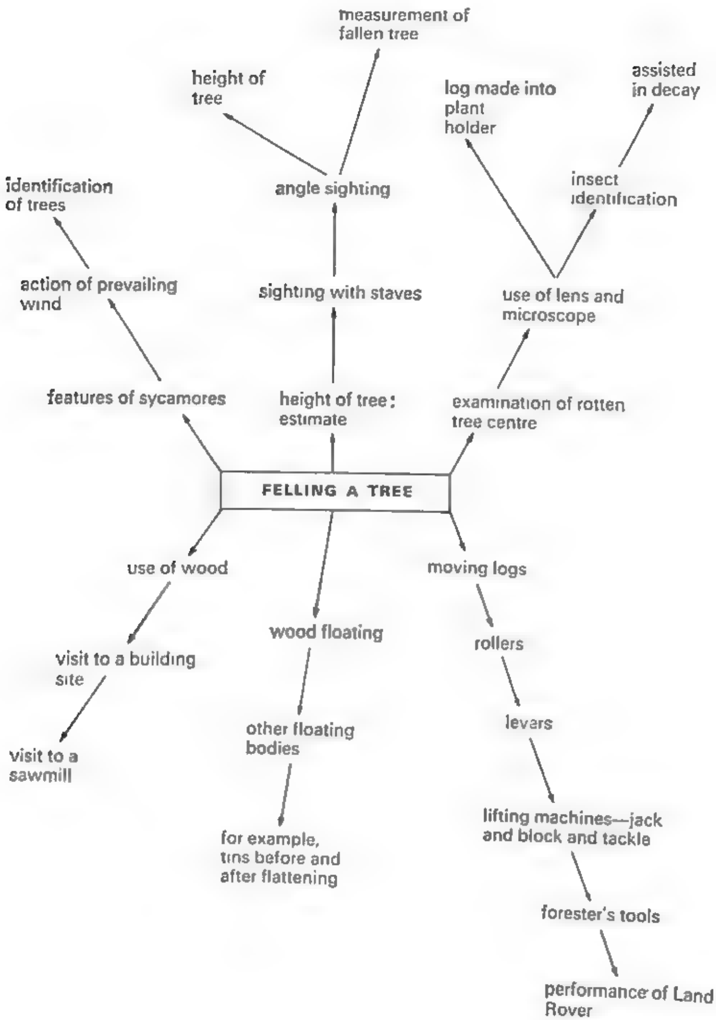
they added a wooden base to it to make an attractive plant holder. They placed this in the entrance hall of the school.

Some of the logs could be lifted easily by the boys; others could not. A discussion followed on the problems of moving heavy objects, and ways of moving the heavier logs were devised. Some were rolled on level ground and up sloping planks. Others were placed on rollers by levering up the ends, and were pushed. The teacher introduced a car jack and a simple pulley system and these were tested. A class discussion extended to the movement of timber in forest areas by shoots and rivers. Another group then examined wood floating and experimented with other objects. Tins that floated in water were flattened in a vice to see if they still did so.

A group of girls began collecting samples of wood that had been put to different uses. They later visited a building site and a local sawmill.

Many questions arose in the course of the investigations. Some produced interesting discussion; many were little more than conversation at the time. One girl asked how wood was made into paper but was obviously not interested in finding an answer. A subject which stimulated a lively discussion among the boys was the performance of the Land Rover used by the Council felling party

Every pupil asked questions but there was considerable variation in depth of interest. Some would have been quite happy to make collections or draw pictures and leave questions unanswered. Others wanted to jump from one interest to another. Approximately one-third of these children showed the thought and persistence necessary to follow a question through to a satisfactory conclusion.


measurement of fallen tree
height of tree
log made into plant holder
assisted in decay
identification of trees
angle sighting
insect identification
action of prevailing wind
sighting with staves
use of lens and microscope
features of sycamores
height of tree: estimate
examination of rotten tree centre
FELLING A TREE
use of wood
moving logs
wood floating
rollers
visit to a building site
levers
other floating bodies
visit to a sawmill
lifting machines—jack and block and tackle
for example, tins before and after flattening
forester's tools
performance of Land Rover

Comments on the classroom examples

This chapter is an attempt to look at the examples quoted throughout the *Teacher's Guides* and to pick out any general trends which emerge.

The work could be considered in terms of many different factors, but we shall concentrate on three things—the starting points, the subject matter, and the teacher's role, since they are the ones that teachers most frequently ask about. It will be important, of course, not to read too much into the limited amount of evidence, coming from what is necessarily a small sample. But if this is kept in mind, it may still be possible to search for suggestions and trends. However, a carefully planned investigation, using a far larger sample, is necessary if precise statements are to be made.

The starting points for study

The examples show that scientific enquiries may arise in a variety of ways, and the starting points range from very general ones, outside the classroom (a riverbank or a piece of waste ground), to apparently narrower and more restricted ones, such as day-old chicks, electricity, or sound. But whatever the start of the investigation, a wide range of enquiry usually developed from it.

How the starting points were chosen

1 Sometimes, the start was deliberately engineered, or even imposed, by the teacher, who knew that a good investigation would come only when the children were actively involved. The day-old chicks (p. 47) were introduced into the classroom by the teacher; so were the sound materials (p. 62) and the electric torch (p. 50); and it was the teacher who decided to consider the weather saying 'A haw year, a snaw year' (p. 173).

2 Some teachers preferred to let the work arise by suggesting one or more possibilities and discussing them with the children. For instance, the teacher and class together chose to study a piece of parkland (p. 74), but later to restrict themselves to a study of trees.

3 There were occasions when a teacher recognized and used an opportunity which arose spontaneously. Other enquiries started from a child's comment or question. On p. 187 we read that 'Keith could hardly wait to tell everyone, "There's a beehive on the common!"' And so he began a study of a piece of urban wasteland, because the teacher made use of the enthusiasm that Keith's comment had aroused.

4 Some starting points were connected with areas of learning other than science. On p. 93 there is an account of how the Breton

fisherman's prayer led some seven- to eight-year-old children to a study of the sea shore, while a chance question by the teacher about a story he was reading started some nine- to ten-year-olds on an investigation of water (p. 141). History, or a schools broadcast, may be equally effective, and on p. 88 we are told how a broadcast programme about the Romans combined both of these stimuli.

5 In some cases, especially in infant classes, there was no single starting point. 'A variety of things', and 'Goldfish, worms, snails, frost, and ice' (*Teacher's Guide 1*, Chapter 2), are particularly good examples.

6 Sometimes, things took a very different line from what was intended or anticipated, and the work developed as it did because of the teacher's flexibility. In 'Stone-age art materials' (p. 80) the headmaster was a keen astronomer and intended to make astronomy his starting point. Instead, the science began when he and the children were discussing the Stone Age, and David asked, 'What did they paint with?' To abandon carefully prepared plans, and take up a new idea at such short notice, demand flexibility and confidence on the part of the teacher.

The work which developed from different starting points

The work described began in a great variety of ways, sometimes inside the classroom, sometimes during or following a class visit. Some starting points were of an extremely general nature, others were apparently quite restricted. Yet in every case there was a development of scientific enquiry to a greater or lesser extent.

Similarly, the work may have started by involving different proportions of the class. In 'Parkland' (p. 74) it was the whole class with their teacher who tackled the general problem. In 'Urban wasteland' (p. 187) the teacher threw the child's observation to the whole class, but the work soon followed divergent lines, even though all the children began at the same point. From a very early stage, some of them were studying insects, others drawing maps, and yet others were investigating the physical materials they found.

Often the work was not restricted to any one of the traditional areas of science, and 'A woodland visit' (p. 191) resulted in studies of trees, insects, spiders, stones and rocks, flotation, and surface tension. Frequently the work in science was inseparable from other aspects of the curriculum, and it was common for children to make graphs, do computation, paint pictures, make models, draw maps, read history, or write prose and poems, *but their excursions into other disciplines were not forced or contrived, and arose as a natural development of the work in hand.*

Sometimes only a few children were involved, or even a single child, and as might be expected this was particularly evident in infant groups. 'Rats' (p. 11) interested small groups or individuals from time to time, but a notable exception was 'Electricity' (p. 50) where the whole class, most unusually and untypically of infants, maintained a prolonged and intense interest in the topic for several weeks.

The depth of study varied considerably, and although it is difficult to make an assessment, it seems clear that much of the work ranged widely over a considerable area of science, with casual observation playing a large part. However, it would be wrong to assume that an *apparently* casual observation was, indeed, casual or that only little was learned. There was also a good deal of work which was carried out in depth, e.g. in 'Electricity' (p. 50) and 'Sound II' (p. 135).

From the work under consideration it seems to be impossible to say that any one starting point, or kind of starting point, i.e. restricted or general, physical or biological, is any better or more productive of enquiry than any other. It would be dangerous to read too much into the limited evidence, and what any teacher considers the criteria of a good starting point must necessarily depend on his own beliefs about the aims and purpose of education. It may be, of course, that the nature of the work that develops is related

to other factors as well as to the starting point.

Some factors which seem to influence the development of the scientific enquiries originating in a given starting point

1 The stage of development of children

The expected pattern would be that younger and less experienced children and slower learners would show only brief and passing interests. This showed itself in much of the work done by infant classes, as 'A teacher's diary', (p. 24), suggests. The slow learners who studied 'Sea-coal' (p. 165) and 'Candles' (p. 167) show the same transitory interest and limited desire, or capacity, for perseverance.

The infants who studied 'A variety of things' and 'Goldfish, worms, snails, frost, and ice' (*Teacher's Guide 1*, Chapter 2) showed the same rapidly changing wide range of interest. On the other hand, a six-year-old boy sat for an hour each day for a week to record bird numbers ('Day-old chicks' p. 48), and rock pools became the centre of seven-year-old children's interest for about four weeks ('The sea shore' p. 95).

The different responses of older and younger children are interesting. It seems that older children, while they still need basic sensory experience similar to the infants', pass through that stage more rapidly. They do more experimenting, bringing to bear the greater range of techniques at their disposal. Their wider experience enables them to give more realistic explanations of their observations, although the infants' guesses will be just as reasonable to *them* in the context of their own limited experience.

For example, we might compare the responses of the older junior children to problems of pitch or frequency ('Sound II,' p. 135), with those of the infants ('Sound I,' p.62). The older children considered that pitch might be varied by changing the length, tension, or thickness of a string, and devised sophisticated equipment to test their ideas. The infants suggested it depended on the letters on the bars, the thickness of the bars, the colours, weight, notches, and shapes of the bars. Each of those had to be considered before a reasonable answer (in adult terms) could be found, and yet all the suggestions made were reasonable to those particular children in the light of their own past experience.

However, once the range of possibilities had been narrowed, the six- to seven-year-olds came to understand many of the things that were discovered by the older children (p. 64).

Most of the science, throughout the complete ranges of age and ability, was observational, with the children not usually seeking theoretical explanations of their observations. It appears, however, that while younger children rarely go beyond observation and comment, older children learn to put forward and test explanations. It should be noted, however, that younger children will often explain, but will not, or cannot, test their explanations. So we find that five-year-olds observed and described rats (p. 11), and on only one occasion did they try to perform an experiment to test their ideas about what they had observed.

Older children planned experiments, but even then they learned mostly through direct observation. Probably it is not until children grow older, when their experience widens, and their intellectual ability develops, that we find some of them asking for theoretical explanations (e.g. an explanation of sound waves, p. 138). Even then, the picture is far from simple, for there are infants whose questions or comments appear to demand theoretical explanations (Paul extracting sound frequencies, p. 63) just as there are much older children who still work at a similar level to infants ('Sea-coal', 'Candles', pp. 165 and 167).

2 The nature of the starting point itself

Some people believe that certain kinds of starting points are more productive of enquiry than others. This is usually said of biological,

as opposed to physical starting points, or of outdoor as opposed to indoor—especially when the indoor starting point is a single piece of equipment.

At first sight, there appears to be some substance in this argument. Certainly the juniors who studied 'Parkland' (p. 74) pursued their enquiries into a wide range of topics—insects, trees, timbers, transpiration, fungi, mathematics (sampling, graphs, computation), art, spoken and written English, history, and so on. Similarly, 'Urban wasteland' (p. 187) shows how a trip to some waste ground ended in learning about movement, variety of organisms, life cycles, strengths of materials, mapping, and the inevitable mathematics, English, and art.

On the other hand, work which began with an electric torch in the classroom ('Electricity', p. 50) remained a study of electricity for a considerable time, and the children who discovered a spectrum on the floor of a school hall ('Rainbow colours', p. 69) were mostly concerned with light—reflections, refraction, and colour mixing. But electricity did result in time measurement (p. 54) and the study of rainbow reflections included work with soap films in wire frames (p. 71).

3 Materials provided by the teacher

Nevertheless, it would be dangerous to read too much into the evidence given above. If at some stage in the electricity study (p. 50) the teacher had brought into the classroom objects like an electric fire, a car headlamp with its reflector, an electric fan, a battery-driven toy, or an electric toothbrush, what then? Which way would the children's interests have gone? And when the 'Rainbow colours' class (p. 69) had become interested in colours, what if their teacher had introduced tins of paint, dyes, inks, printed fabrics, or a collection of flowers? What effect would these materials have had on the course of the investigation?

The presence of a class microscope started an interest in fungal spores ('Leaves' p. 117) and the interest of the same class in trees was revived when logs and pieces of wood were brought in. A metronome on a clock table ('A schools broadcast' p. 88) enabled Derek to adjust his pendulum length for a one-second swing. The fact that there were tape measures, yardsticks, or kitchen scales regularly available, made the children constantly aware of the possibilities of measurement. Much, then, will depend on the range of materials available, and this in turn will depend on the teacher's awareness of possibilities (that is, to some extent on his own scientific background) and also on the availability of materials to the teacher—for example, can every school afford to buy a metronome or a stopwatch even if the teacher would like to have them?

Similarly, the general source material of the classroom, in terms of books, charts, film strips, retort stands, magnets, etc. will play an important part. Thus, Lorraine ('Angling' p. 202) borrowed a book and read about the number of fish which can be kept in relation to surface area of water. This started her on an enquiry of her own.

Children studying wasps ('A visit to the school grounds' p. 145) read about how wasps made paper and decided to make some themselves. The work of the same group was enhanced, facilitated, and influenced by the class store of things such as various glues, sawdust, balsa cement, wire, perforated zinc, and glass jars.

It is reasonable to expect children to use the materials and equipment in regular everyday use in the classroom, and the greater the range of basic source material the wider the possible scope of the work which develops.

4 The teacher's ability to anticipate possible enquiries, and/or to appreciate the child's comment or question and help him to follow it up.

It may be that the limited range of some investigations is to some extent due to the teacher's equally restricted background of science, since that will limit his awareness of

the possibilities inherent in the situation. Do pieces of waste ground, parks, or farms, initiate more widely ranging investigations simply because they include more *obvious* things to enquire about? *If* teachers and children had more experience of asking questions and seeking answers; *if* teachers had a broader background of science; *if* there were more books of the right kind for teachers and children to read; would we then find that bits of plastic, batteries and bulbs, or handbag mirrors, might take on new and exciting dimensions as starting points for scientific enquiry?

The subject matter and the child

There are those who wonder if some subjects are more suitable for boys, others for girls, and if there are some things which children of eight can understand but children of seven cannot. Should the teacher contrive, or adjust, the content of what he teaches to suit the sex and age of his class? Is there such a thing as progression? After all, traditional science teaching at the secondary and further educational levels has suggested that it is preferable to teach things in certain sequences. Is this true at the primary stage?

The examples quoted suggest that many of the topics can be used at any stage, provided that the enquiries develop from the children's questions and interests, i.e. that they have significance for the children.

On pp. 135 and 62, there are descriptions of two classes which studied sound, one of them of nine- to ten-year-olds, the other of infants. The subject was new to each group, and there are some notable parallels. Both sets of children discovered the connection between sound and vibration, and they both used what was essentially the same method of investigation—i.e. making things sound, and then watching and feeling the vibrations. Two of the younger children went so far as to suspect that air can vibrate. Both groups learned something about frequency. The more limited experience of the infants is revealed in their suggestions about how bars of the same length can produce different notes, but apart from details of this kind, the two investigations show a remarkable similarity.

There is a similar parallel between the study of electricity done by infants and that done by older juniors. Many groups examined the structure of a bulb, the brightness of the light using different numbers of bulbs and batteries, conductors, and insulators and, apparently with a similar degree of understanding. In many ways, the infant work quoted in 'Electricity' (p. 50) was a more detailed and searching study than that of the older children.

Whenever similar work was done by different children, there was no evidence that the subject matter was dealt with in any particular sequence. Children of different age, studied insects, their life cycles, their methods of movement, apparently in no set orders Different aspects of water were dealt with. as described in 'A story read to the class', p. 141, by different children, apparently in no logical sequence.

Such evidence as there is, therefore, suggests that many of the topics tried can be used with children of different ages. What any child learns will depend on his past experience, and while *it may well be that for any one individual* there are some topics which are better dealt with sequentially, we are always faced with the problem of not being aware of more than a tiny amount of a child's past experiences and what he already understands. *The most reliable guide, therefore, to an appropriate sequence, does not seem to be the logical structure of the subject matter, but rather the questions asked by the child as he handles and explores the materials, and pursues his enquiries.*

Just as it is impossible to relate precisely subject matter and age, so it is impossible to define certain topics as being suitable for boys while others are for girls. The suggestion that physical science is for boys and biology for girls is not borne out by the evidence. As the 'Parkland' study shows (p. 77), David, aged 10, was interested in trees. In the science starting from a story (p. 141) it was three

nine-year-old girls who investigated the porosity of rock. Barbara was the child who asked why sponge rubber changes colour when it gets wet ('Urban wasteland' p. 189). The girls in 'Sound II' (p. 135) were equally interested and just as deeply involved as the boys. Throughout all the examples, and over the complete age range, boys and girls showed similar interest in biology and the physical sciences.

However, two general comments need to be made. First, in relation to the development of work with children of different ages. Clearly, the teacher adjusts the *level* of the work to the experience and ability of the children, by the response he makes to their questions and comments, and through the materials, books, etc. he provides. In this way he opens up and develops enquiries at what he judges to be the children's level of understanding. Hence the vital role of discussion.

Secondly, in the examples quoted, the starting points were all related to the age of the children, in the sense that they were selected because it was thought they would offer *something* to *most* of the children in the class. The significance, here, for the teacher, is not that *some* child will get *something* from any starting point, but that there are some starts from which *most* children will get a *great deal.* This may be why the general starting points, like waste ground, or parks, seem to have such great value, and why the 'variety of things' (*Teacher's Guide 1*, Chapter 2) in the infant classroom produced such a plethora of investigation.

The role of the teacher

In all the examples of work described, there are frequent references to the teacher's interventions, comments, and decisions. It is clear that without the teacher, very few enquiries would have developed or, having developed, would have been sustained, but it is extremely difficult to ascribe to him any *set* roles. Nevertheless, there are some general comments which might be made.

1 Initiating enquiries

In many cases the work had its roots in the teacher's decision to take a class on a visit, or to bring certain materials into the classroom. At other times, the work began because the teacher recognized possibilities in a child's question or comment.

2 Influencing the course of an investigation

In every case, the teacher influenced the course of the investigation by offering suggestions, posing problems, giving explanations, introducing books or equipment, etc.

In 'A weather saying' we learn (p. 174) that, 'The teacher himself had searched the literature to prepare for the development he anticipated', and that 'Vitamin C content was mentioned without elaboration, but with the thought that questions might arise.'

When Derek and his friends were timing the swing of a pendulum ('A schools broadcast' page 91) the teacher '. . . wondered if a bigger piece of Plasticine would make any difference.'

Sometimes the children asked the teacher for definite suggestions about what to do: 'Rosalind and Margaret approached the teacher, saying, "We don't want to do slugs any more. What shall we do?" ' ('A school playing field' p. 132). Sometimes the teacher stepped in and taught when it seemed appropriate to do so, and when it helped the children to clear the immediate hurdle and continue their investigations. Thus, 'The teacher suggested that they should look on the wall to see if there were any creatures there which might have eaten them' ('A school playing field', p. 131); and in 'Sound II' (p. 138) '. . . they asked the teacher to tell them more about sound waves . . . he enlisted the help of a science teacher from a nearby secondary school. He showed them a film about sound waves, and set up an oscilloscope so that they could see the trace made by their own instruments and tuning forks.'

On occasions, the teacher had to make definite decisions about what line of study

should be taken. In 'A farm visit' (p. 207), when the children had decided to incubate eggs, they encountered great difficulties with the circuitry of the thermostat. The teacher then had to make up his mind whether to let the investigation follow a completely new line about circuits, *or* to tell the children how to wire the circuit, *or* to provide them with books which would help, *or* to provide them with a commercial incubator so that they could get on with the work they had started. In the light of his knowledge of the children with their enthusiasm for, and involvement in, the problem of egg incubation, he decided on the last one of the possible courses.

3 Creating a suitable climate within the classroom

At the basis of every successful piece of work are the good personal relationships which exist between the teacher and the individual children. This is reflected not only in the general accounts, but also in the occasional comments of the teachers.

> '. . . This experiment has proved to me the real value of the less structured approach and the way in which the children have worked is the criterion.' ('A schools broadcast', p. 91).
>
> 'Individual and small group conversations led to more concrete observations than did class discussions.' ('Rats' p. 13).

And the recognition that children are not just miniature adults:

> 'The things that interest children are always surprising to an adult.' (Rats' p. 13).

The work described also makes it clear that teachers adopt different degrees of formality in their classrooms, and that it would be very wrong for anyone to equate formality with bad teaching and informality with good. Exactly how informal and flexible any classroom situation will be must depend on a number of factors, not the least of which is the teacher's own confidence to handle the situation effectively.

4 Discussion

In almost every example there are references to the great importance and value of discussion. We frequently read that the teacher discussed the general problem with the class; or that when a group or individual was having difficulty, the teacher discussed it with the pupils or pupil, sometimes bringing in another group, sometimes throwing the problem to the whole class. Always, there seem to have been discussions about problems, about experiments, about apparatus, about observations and evidence.

5 Anticipation

In almost every case there are examples of teachers anticipating children's future needs in terms of books, equipment, charts, films, or materials which could be used for communication (e.g. the presence of wire, paper, and paste, in 'A visit to the school grounds' p. 148), and usually a large enough variety was supplied to offer alternatives to the children.

On reading through the examples, one is impressed by the way in which the teacher has ceased to be a figure who stands in front and talks at the children. Repeatedly it is revealed that, through their common interest in the materials with which they were working, children and teacher established close personal relationships, and that success grew as the teacher found time to observe and study his children closely. It seems, too (and knowledge of the actual events bears this out) that as experience grew, informality and flexibility of approach extended. Compare, for example, 'Bricks' (p. 151) and 'Glass' (p. 157).

Children and teachers also accepted the undifferentiated nature of the environment. Mathematics and art, as well as science, were used as different but equally important aspects of the same enquiry. Science was seen as just one of the ways by which children will learn; not the only way, but a truly effective one, especially when it is not used in isolation.

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